Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

by

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BSc (Hons) in Quantity Surveying

A thesis submitted for the degree of

Doctor of Philosophy (LPHD)

Science, Technology, Engineering and Mathematics (STEM)



University of
South Australia

October 2022

This piece of work is dedicated to my beloved father, mother, sister and husband for all the sacrifices they have made to create a better future for me.

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List of Abbreviations

AHP	-	Analytical hierarchy process
AI	-	Artificial intelligence
AISC	-	Australian Industry and Skills Committee
BBN	-	Bayesian belief network
BIM	-	Building Information Modelling
BPO	-	Business process outsourcing
CCTV	-	Closed-circuit television
CDW	-	Construction and demolition waste
CIOB	-	Chartered Institute of Building (UK)
CLSC	-	Closed-loop supply chain
CPT	-	Conditional probability table
DAG	-	Directed acyclic graph
DIT	-	Department for Infrastructure and Transport (SA)
D-map	-	Dependence map
DW	-	Demolition waste
EoL	-	End-of-life (phase)
EPA	-	Environmental Protection Authority (SA)
EU	-	Epistemic uncertainty
EU	-	European Union
FMEA	-	Failure modes and effects analysis
FMECA	-	Failure mode and effects criticality analysis
FSC	-	Forward supply chain
FT	-	Fault tree
GDP	-	Gross domestic product
GISA	-	Green Industries SA
I-map	-	Independence map
IoT	-	Internet of Things
IPCs	-	Information processing capacities
IPMs	-	Information processing mechanisms
IPNs	-	Information processing needs
ISO	-	International Organization for Standardization
IT	-	Information technology
JHA	-	Job hazard analysis
MRF	-	Materials recovery facility
MT	-	Megatonne/s
NATA	-	National Association of Testing Authorities (Australia)
NGOs	-	Non-governmental organisations

NIR	-	Near infra-red (technology/spectrometer)
NSW	-	New South Wales
OIPT	-	Organisational information processing theory
OMC	-	Optimum moisture content
PCA	-	Potentially contaminated activity
PNs	-	Petri nets
PPE	-	Personal protective equipment
QA	-	Quality assurance
QAS	-	Quality assurance system
QC	-	Quality control
QM	-	Quality management
QMS	-	Quality management system
RAC	-	Recycled aggregate concrete
RCAs	-	Recycled concrete aggregates
RFID	-	Radio-frequency identification
RL	-	Reverse logistics
RLSC	-	Reverse logistics supply chain
RPE	-	Respiratory protective equipment
SA	-	South Australia
SD	-	System dynamics
SLR	-	Systematic literature review
UAE	-	United Arab Emirates
UK	-	United Kingdom
USA/US	-	United States of America/United States
WDF	-	Waste-derived Fill (Standard)

Abstract

Due to the alarmingly large volumes of demolition waste (DW) being generated, the construction industry has been prompted to urgently embrace sustainable approaches. With this, the concept of managing DW through reverse logistics supply chains (RLSCs) has gained momentum. Despite efforts to promote RLSCs, the inferior quality of reprocessed products continues to be a make-or-break factor for RLSC adoption in the construction industry. An integrated system of quality assurance (QA) plays an important role in the RLSCs of DW; however, it is adversely impacted by information deficiencies in supply chains. As posited in the theoretical underpinnings of organisational information processing theory (OIPT), information deficiencies create epistemic uncertainties that lead to information processing needs (IPNs), to which internal stakeholders in RLSCs should respond by undertaking appropriate information processing mechanisms (IPMs). The body of related literature has posited that these epistemic uncertainties in a supply chain are not isolated but integrated. However, no previous study has investigated epistemic uncertainties and IPMs for QA, nor has any study explicitly modelled the effect of interrelated epistemic uncertainties on an operational performance criterion, such as quality assurance (QA). Therefore, the current study aimed to develop and empirically validate an information processing model by identifying and assessing the interrelationships between epistemic uncertainties for QA in RLSCs of DW.

The study followed an exploratory four-phase sequential mixed-methods approach to accomplish its aim. In the first phase, 30 semi-structured interviews were conducted with internal and external stakeholders in RLSCs of DW to collect qualitative data which were analysed through directed content analysis. This phase empirically established that the aspects of process, people, policy and technology contribute to QA in RLSCs of DW. Furthermore, 16 epistemic uncertainties, comprising six macro-level, two meso-level and eight micro-level uncertainties, as well as 15 IPMs for QA, were identified in this data collection phase. The study's second phase aimed to develop an information processing causal map for QA in RLSCs of DW by conducting 20 structured interviews with experts in the DW management sector. The collected data were analysed through nine logical tests using statistical methods. Complying with the

principles of the causal mapping approach, in this phase, the developed causal map was transformed into a Bayesian belief network (BBN)-based conceptual information processing model. The model comprised 45 cause-and-effect relationships. In the third phase, a focus group discussion was conducted with five experts in the DW management sector to empirically validate the BBN-based conceptual information processing model for QA. Accordingly, through empirical validation, 15 new relationships between epistemic uncertainties were added to the model while two links between IPMs and epistemic uncertainties were deducted. In this BBN-based conceptual information processing model, the macro-level uncertainties appear at the bottom of the model, indicating that they cause the remaining meso- and micro-level uncertainties. The empirically validated conceptual model was applied in the last phase to assess the applicability of analysing information processing for QA using two RLSC cases. In this phase, the study found that, compared to RLSCs with large-scale organisations, the RLSCs with small and medium-scale organisations were more vulnerable to macro-, meso- and micro-level uncertainties for QA.

In practical terms, this study's information processing model for QA contributes to practitioners in RLSCs of DW, enabling them to gain a greater understanding of the impact of epistemic uncertainties on QA within the supply chain. The model also informs practitioners about which IPMs should be undertaken in response to specific epistemic uncertainties and, if undertaken, their effect on reducing the probability of those epistemic uncertainties occurring. This study contributes to the knowledge by investigating an overlooked area in the discipline and making a synthesis between information processing and QA that has not previously been made. Since the current study focuses only on the supply chains to manage DW, future research could investigate information processing for QA in RLSCs of construction waste. Furthermore, future studies could apply the findings of the current study, which are only limited to South Australia (SA), to varied geographical contexts while distinguishing the differences in the results based on varied technical, legal and socio-economical attributes.

Keywords: demolition waste (DW); epistemic uncertainties; information processing needs (IPNs); information processing mechanisms (IPMs); organisational information processing theory (OIPT); quality assurance (QA); reverse logistics supply chains (RLSCs)

Declaration

I declare that:

This thesis presents work carried out by myself and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, are clearly acknowledged.



Madduma Kaluge Chamitha Sanjani Wijewickrama

Date: 20/10/2022

Acknowledgments

I sincerely thank all the individuals and organisations who supported me during my PhD journey.

First and foremost, I would like to express my heartfelt gratitude to my principal supervisor, Associate Professor Nicholas Chileshe, for his excellent and continuous guidance, support and care throughout my PhD journey. He inspired me carefully and conscientiously over these three and half years to help make me the person I am. Furthermore, I express my sincere gratitude to my co-supervisors, Associate Professor Rameez Rameezdeen and Dr Jorge Ochoa Paniagua, for their continuous support throughout my study. The excellent insights, wisdom, and critical and analytical thinking of all my supervisors inspired me greatly during my study, and their valuable time, effort and support expended on my behalf will be forever appreciated. I must also thank the industry supervisor of my research, Mr Jim Fairweather, for his active involvement in this research and his support during the data collection.

I further extend my sincere gratitude to the academic and non-academic staff of the University of South Australia for providing an appropriate environment and facilities for my studies. Among these staff, I would especially like to thank Dr Guna Hewa, Adjunct Professor David Ness, Dr Thilini Jayawickrama, Dr Aparna Samaraweera, Dr Ruchini Senarath and Miss Sonali Pandithawaththa for their informal input and advice on my research and their love, support and kindness throughout my PhD journey. Additionally, I am extremely grateful to all my colleagues who were, or who are currently, pursuing the PhD program at UniSA STEM for always supporting me academically, professionally and personally. Moreover, my very special thanks go to the Australian government for offering me financial support through the Research Training Program international (RTPi) scholarship and to the University of South Australia for waiving the tuition fees of my studies through the UniSA International Higher Degree by Research (HDR) fee Offset.

I would also like to take this opportunity to thank all the industry professionals across South Australia who participated in the data collection phases of my study. Without their immense support, this work would not have been successfully completed. In

particular, I will forever applaud the valuable and generous assistance given by Mr Mike Haywood (Principal Consultant, Sustainable Resource Solutions); Mr Peter Butt (Work Health and Safety Manager, Royal Park Salvage Demolition); Mr Jack Mouhalos (Managing Director, Richmond Civil Works); and Mr Andrew Silvestri (Strategic Business Development Manager, ResourceCo South Australia).

I would not have been able to pursue a PhD without the support and guidance from the University of Moratuwa, Sri Lanka. Consequently, my special thanks go to Ch. QS. Suranga Jayasena (Head, Department of Building Economics, University of Moratuwa), Professor Yasangika Sandanayake, Professor Kanchana Perera and Professor Udayanagani Kulatunga for their encouragement and direction in successfully applying for a PhD scholarship. Furthermore, I sincerely thank my school, Mahamaya Girls' College, Kandy, and all its teachers. Furthermore, I wish to thank all my friends in Sri Lanka, Australia, Hong Kong, the United Kingdom (UK) and the United Arab Emirates (UAE) for their support and encouraging thoughts.

Words cannot express my gratitude to my family for their unconditional love, care, support and encouragement. Dear mother, father, sister and brother-in-law, I will forever be in your debt. Last, but not least, I owe my deepest gratitude to my beloved husband, Chathushka. It would not have been possible for me to complete this research without his enduring love, care, support, trust, understanding and encouragement.

Publications

Journal Publications

1. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeen, R & Ochoa, JJ 2022, 'Information processing for quality assurance in reverse logistics supply chains: An organizational information processing theory perspective', *Sustainability*, vol. 14, no. 9, p. 5493. DOI: 10.3390/su14095493

2. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021, 'Managing macro-level uncertainties for quality assurance in reverse logistics supply chains of demolition waste perspective', *Sustainability*, vol. 13, no. 23, p. 13069. DOI: 10.3390/su132313069

3. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021, 'Information-centric influence strategies for quality assurance in reverse logistics supply chains: External stakeholders' perspective', *Benchmarking: An International Journal*, pp. 1-32. DOI: 10.1108/BIJ-05-2021-0276

4. **Wijewickrama, MKCS,** Rameezdeen, R & Chileshe, N 2021, 'Information brokerage for circular economy in the construction industry: A systematic literature review', *Journal of Cleaner Production*, p. 127938. DOI: 10.1016/j.jclepro.2021.127938

5. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeeen, R. & Ochoa JJ 2021, 'Information sharing in reverse logistics supply chain of demolition waste: A systematic literature review', *Journal of Cleaner Production*, vol. 280, p. 124359. DOI: 10.1016/j.jclepro.2020.124359

6. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeeen, R. & Ochoa JJ 2021, 'Quality assurance in reverse logistics supply chain of demolition waste: A systematic literature review', *Waste Management and Research*, vol. 39, no. 1, pp. 3-24. DOI: 10.1177/0734242X20967717

Conference Publications

7. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeeen, R. & Ochoa JJ 2021, 'The role of government towards a circular economy in the construction industry: A systematic literature review, in *Proceedings of the World Conference on Waste Management*, vol. 1, no. 1. pp. 9-22. DOI: 10.17501/26510251.2021.1102

8. **Wijewickrama, MKCS,** Chileshe, N, Rameezdeeen, R. & Ochoa JJ 2020, 'Best practices for diverting demolition waste from landfill: A systematic literature review', in L. Scott & CJ Neilson (eds) *Proceedings of the 36th Annual ARCOM Conference*, 7-8 September 2020, UK, Association of Researchers in Construction Management, pp. 675-684

1 Introduction

1.1 Background

The construction industry is a significant contributor to a country's national economic development. Globally, it contributes, on average, 8–10% to the gross economy, promotes economic growth, provides employment opportunities to the masses, and acts as a broker between other industries and the economies of different countries (Arshad et al. 2017; Opoku et al. 2021). While being the engine of national development, the construction industry also directs the flow of goods and services with other industries (Loosemore 2016; Opoku et al. 2021). According to Robinson, Leonard and Whittington (2021), the global construction industry's contribution to the aggregate world economy was valued at US$10.7 trillion in 2020. For example, in 2020, the construction industry in the United Kingdom (UK) and China contributed 6.0% (Chartered Institute of Building [CIOB] 2020) and 7.2% (Statista 2022) to the national gross domestic product (GDP) of their respective countries. In Australia, the construction industry produces over A$360 billion in revenue per annum, contributing 9% to Australia's GDP in 2021 with a projected growth rate of 2.4% per annum in the next five years (Australian Industry and Skills Committee [AISC] 2022). Furthermore, as Australia's third-largest employing industry, the Australian construction industry's employment levels have increased from 652,800 in 2001 to 1,160,700 in 2021, although a decline in that level was noted from 2020 to 2021 (AISC 2022). However, projections in the same report posit that this employment level will reach 1,263,9020 by 2025. Despite the industry's economic significance, environmental unfriendliness is cited as a vital aspect of criticism of the construction industry (Oke et al. 2019).

The construction industry leads to a plethora of negative environmental consequences, especially as it utilises a significant amount of global natural resources while producing large volumes of solid waste into the environment. Previous studies found that the

construction industry is the world's largest consumer of raw materials (Alsheyab 2022), utilising 40% of global natural resources (by volume) as raw materials (Ajayi & Oyedele 2018). Moreover, it accounts for 30% of all waste generated worldwide (Ginga et al. 2020). The construction industry is the third largest waste generator globally, producing 7–10 billion tons of waste annually (Kaza et al. 2018). For instance, China was the largest producer of construction and demolition waste (CDW), generating around 2,300 million tons in 2019 (Forward Business Information Co Ltd 2020). Furthermore, in 2018, the United States of America (USA) and the European Union (EU) produced approximately 600 million tons and 834 million tons of CDW, respectively (Eurostat 2020; US Environmental Protection Agency 2019). Meanwhile, in Australia, the construction industry generated 27 megatonnes (MT) of CDW in 2020 (National Waste Report 2020), with this being the largest source of waste in the country (Shooshtarian et al. 2022). Amid the different waste management options available, the construction industry continues to prefer landfill which is comparatively more economical and convenient (Chileshe, Jayasinghe & Rameezdeen 2019). It is estimated that 60% of CDW is disposed of in landfill worldwide (Ferdous et al. 2021). For instance, in Australia, only 44–47% of CDW is recycled; thus, more than 50% is destined for disposal to landfill without being recovered (Pickin et al. 2018). Throughout the life cycle of a project, CDW is generated from activities related to construction, renovation and demolition (Jin et al. 2017; Wu, Z et al. 2014). Of the total CDW, demolition waste (DW) accounts for more than 70% (Chen, K et al. 2021; Wu, H et al. 2016). Moreover, the waste generated per unit of a demolition site's gross floor area is 50 times more than the waste generated on a new construction site (Butera, Christensen & Astrup 2014). Consisting of a highly heterogeneous blend of inert and non-inert waste, DW contains hazardous and non-treated materials (Wu, H et al. 2016; Yu, B et al. 2019). Even if most waste types in DW could be reprocessed (e.g., concrete, metal, timber, bricks, etc.), they are often directed to landfill, creating many detrimental effects for the environment, the economy, public health and society (Wang, J et al. 2019). To address these concerns, sustainable approaches, such as reuse and recycling, have been researched, attempted and practised in the construction industry over decades (Ferdous et al. 2021; Kleemann et al. 2017).

In this context, reverse logistics supply chains (RLSCs) have captured the construction industry's attention as a viable approach for providing infrastructure to manage DW

efficiently and effectively. According to Balasbaneh and Ramli (2020), the forward supply chain (FSC) in the construction industry comprises the individuals and organisations involved in all construction phases, namely, raw materials extraction, construction, operation and maintenance, and end-of-life (EoL) of a building. Therefore, the construction FSC is commonly acknowledged by the notion of 'from the cradle to the grave' (Guarnieri, Cerqueira-Streit & Batista 2020), with the cradle referring to the natural resource extraction phase and the grave being the EoL phase of a building. In contrast, the RLSC starts from the EoL phase of a building, in which DW is collected after building dismantling and then attempts are made to manage it by undertaking different strategies, including reuse, recycling, remanufacturing and, lastly, disposal of the residue (van den Berg, Voordijk & Adriaanse 2020). Therefore, the RLSC is a process that focuses on moving materials and related information from the point of the dismantling of buildings to the point of new construction to recapture the value of waste that would otherwise be disposed of in landfill (Hosseini et al. 2014; Rogers & Tibben-Lembke 1999). Consequently, the FSC and the RLSC form a closed-loop supply chain (CLSC) in the construction industry, promoting the concept of 'from cradle to cradle' (Ashby 2018). In this regard, RLSCs follow a more sustainable approach, in which the waste at the EoL of a building serves as input resources to the FSC, thereby reducing reliance on landfill and incineration as the only strategies for DW management (Tennakoon, Rameezdeen & Chileshe 2022).

An RLSC follows a chain of activities to introduce reprocessed products from DW back to new construction sites in the forward supply chain (FSC). Accordingly, it encompasses several stages: dismantling, collection, separation, sorting, treatment, reprocessing and redistribution (Brandão et al. 2021a). Generally, two organisations with different interests are involved in the operations of an RLSC of DW (Schamne & Nagalli 2016; Wijewickrama et al. 2021b). One is involved in stages related to the building dismantling and on-site processing phase (i.e., dismantling, collection, on-site sorting and transportation of salvageable waste), while the other is engaged in stages associated with the off-site waste processing phase (i.e., reprocessing and redistribution). These internal stakeholder organisations excel in waste recovery by diverting waste from landfill and converting it into usable products to be introduced to the secondary market after reprocessing. To ensure the effectiveness of these operations, Chileshe, Jayasinghe and Rameezdeen (2019) emphasised the importance of sharing

information between these phases efficiently and effectively. Information sharing would enhance the collaboration between internal stakeholders in RLSCs, thus advocating for delivering quality products on time at a reduced cost (Wijewickrama et al. 2021b; Wu, Z et al. 2022).

However, as reported in the literature, RLSCs of DW do not benefit from a well-organised information flow (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b; Wijewickrama, Rameezdeen & Chileshe 2021; Wu, Z et al. 2022). Chileshe, Jayasinghe and Rameezdeen (2019) asserted that information sharing has been challenging in RLSCs due to the dispersed locations of process facilities and the difficulties in predicting the location, time and quantity of waste. Wu, Z et al. (2022) revealed that market uncertainty, lack of trust and lack of government support are the three most significant barriers inhibiting information sharing in the RLSCs of DW, with information deficiency leading to many adverse effects. The lack of information disrupts the smooth and efficient flow, resulting in chaotic progress in the RLSC operations (Li & Lin 2006; Tennakoon, Rameezdeen & Chileshe 2022). As information is the key ingredient for decision making, internal stakeholders in RLSCs find it difficult to make the right decisions at the right place and time due to RLSC information deficiency (Wijewickrama et al. 2021b). In contrast to the traditional FSC, the RLSC is subjected to more challenges in practice (Correia et al. 2021); however, producing quality reprocessed products is the make-or-break concern for reverse logistics (RL) implementation in the construction industry (Pushpamali et al. 2021). Although various reasons are given for quality issues in reprocessed products, many previous studies highlighted that the lack of useful information is the root cause (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021a; Xia & Bakker 2014). For instance, Xia and Bakker (2014) revealed that information deficiency hinders quality management (QM) approaches in RLSCs, irrespective of their industries. From the construction industry perspective, Wijewickrama et al. (2021a) emphasised, via proposing a conceptual framework, that quality assurance (QA) efforts in RLSCs of DW are disrupted due to the absence of useful information. Meanwhile, Jayasinghe, Chileshe and Rameezdeen (2019) claimed that quality issues in reprocessed products and information deficiency in RLSCs are interdependent and related. Many efforts have been made, especially via literature reviews, to affirm the relationship between quality

issues in reprocessed products and information deficiency in RLSCs of DW; however, subsequent investigations are minimal. To date, no empirical research has investigated how information deficiency causes quality issues in reprocessed products and what mechanisms could be implemented to locate and process information to address this deficiency. Against this background, the current study is a progression toward addressing this research gap.

1.2 Statement of the Problem

The inferior quality of reprocessed products is a significant barrier to RL adoption in the construction industry. In this industry, end-users have attached a stigma to the negative perception of buying reprocessed products due to their labels, such as ‘reuse’ and ‘recycle’ (Pushpamali et al. 2021; Shooshtarian et al. 2020). However, compounding this negative perception, construction industry practitioners have experienced quality issues in reprocessed products in practice (Chileshe et al. 2016; Trochu, Chaabane & Ouhimmou 2018). For instance, in their study, Chileshe et al. (2016) revealed that industry practitioners in South Australia (SA) had encountered a mushroom effect on the road surface due to reprocessed bitumen being mixed with tiny wood particles. They also found that the concrete formed from recycled concrete aggregates (RCAs) set more quickly than virgin concrete due to cement in these aggregates. To encourage end-users to buy reprocessed products, the quality of these products should be at least equivalent to the quality of virgin materials (Pushpamali, Agdas & Rose 2020; Ravi & Shankar 2005; Shooshtarian et al. 2020). However, these authors further stressed that this has been challenging in RLSCs as no assurance is given about maintaining the same quality and performance of reprocessed products throughout the process. Consequently, despite greater efforts to promote RL, the inferior quality of reprocessed products is still a confronting barrier to its adoption in the construction industry.

Producing end-products of inferior quality does not happen by chance. Most quality-related issues in products are found to be caused by inappropriate manufacturing processes (Ghadge et al. 2017; Sheikh et al. 2019). Therefore, product quality primarily depends on the extent to which quality is assured within the production process. Given this, the two aspects of quality with which RLSCs of DW should be concerned are process quality and product quality. It may not be possible to produce good quality products without following a systematic process of assuring quality during all phases of

an RLSC (Jayasinghe, Chileshe & Rameezdeen 2019; Nikolaidis 2012). Previous studies claimed that issues related to quality control (QC) and compliance were found in RLSCs of DW (Chileshe et al. 2014; Chileshe et al. 2016). However, Nikolaidis (2012) asserted that QC is the 'old fashioned' mode of QM, as it aims to detect non-conforming output rather than preventing it. Therefore, rather than taking a detection approach like QC, a prevention approach could augment customer satisfaction by preventing non-conforming products from being produced (Ghadge et al. 2017; Sheikh et al. 2019). In this regard, QA, a process-centred, systematic approach to determining whether the product meets the specified end-user requirements, plays an important role in the RLSCs of DW (Wijewickrama et al. 2021a). In a prevention approach like QA, product quality is determined by process quality, directed by inputs in the supply chain, such as methods, people, machines, materials, policies and the external environment (Ghadge et al. 2017). Correspondingly, via a systematic literature review (SLR), Wijewickrama et al. (2021a) found that QA in RLSCs of DW is a system comprising four aspects: people, process, policy and technology integrated within an information-centric environment. However, the study highlighted the need for future research to validate the SLR findings by examining the empirical insights on how these aspects contribute to QA in RLSCs of DW.

In fact, the body of literature has recurrently outlined that the lack of useful information is a serious concern in RLSCs of DW (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b; Wijewickrama, Rameezdeen & Chileshe 2021; Wu, Z et al. 2022) due to the supply chain's fragmented, unorganised, cross-functional and multidisciplinary nature (Chileshe, Jayasinghe & Rameezdeen 2019; Chileshe, Rameezdeen & Hosseini 2016). On this point, Wijewickrama et al. (2021b) emphasised that the useful information required for RLSC operations is comparatively scattered, with some trapped within organisations and some not even found within the supply chain. The term 'useful information' refers to an organised body of data or knowledge that is relevant, accurate, timely and concise, and available for making an array of decisions and guided actions (Lotfi et al. 2013; Wijewickrama et al. 2021b). According to the seminal study by Galbraith (1973), circumstances in which the useful information required to make decisions is lacking are known as 'uncertainties'. Later studies defined uncertainties that arise from a lack of information on how a system should behave, ultimately affecting its outcome, as 'epistemic

uncertainties', which could be reduced by processing the required information (Brugnach et al. 2008; Filippi & Vasile 2021; Khanmohammadi 2021; Walker et al. 2003). Meanwhile, Rahimi and Ghezavati (2018) mentioned that due to the deficiency in useful information, various uncertainties formed in the RLSCs of DW that negatively affected the quality of product delivery in the supply chain. In shedding light on this, it could be argued that the QA system (QAS) in RLSCs of DW is adversely affected by epistemic uncertainties; thus, the end-products of the supply chain are of inferior quality.

Consequently, a holistic understanding of the information-centric QA in RLSCs of DW can be presented by the organisational information processing theory (OIPT). The theory posits that epistemic uncertainties due to a lack of useful information create information processing needs (IPNs) to which organisations should respond by adopting appropriate information processing mechanisms (IPMs) (Galbraith 1973, 1974). The theory further argues that the extent to which these organisations' IPNs and IPMs match determines their organisational performance. The central tenet of OIPT is that organisations must process information to reduce epistemic uncertainties as much as possible to achieve organisational performance. In the current study, the term 'information processing' means gathering, interpreting and synthesising information for organisational decision making (Tushman & Nadler 1978). Recent studies have used this theory to underpin their empirical findings to provide useful insights into information processing in RLSCs in the construction industry. For instance, van den Berg, Voordijk and Adriaanse (2020) explained how demolition contractors coordinate the EoL activities of buildings based on the OIPT perspective, with their study focusing only on the building dismantling and on-site processing phase in RLSCs of DW. However, to date, no empirical research has been based on a holistic investigation of epistemic uncertainties for QA in RLSCs of DW and on IPMs that organisations in the supply chain could implement in response, from the OIPT perspective.

The epistemic uncertainties in a supply chain are not isolated but inevitably affect each other. For instance, Peidro, Mula and Poler (2007) stated that epistemic uncertainties are the main concern for decision-making processes in supply chains as they tend to propagate back and forth along the supply chain, thus affecting its performance. Furthermore, Flynn, Koufteros and Lu (2016) asserted that supply chains encompass different uncertainties embedded within the broader classification of micro-, meso- and

macro-level uncertainties, and that these uncertainties interact with each other. Flynn, Koufteros and Lu (2016) noted the need for future research to investigate the different types of epistemic uncertainties encountered by a supply chain and their potential interactions. Correspondingly, as an RLSC of DW is mostly in a dyadic configuration (Wijewickrama et al. 2022), the epistemic uncertainties in one phase could propagate and cause the creation and compounding of epistemic uncertainties in the same phase or the subsequent phase. Furthermore, the interrelationships between epistemic uncertainties could systematically affect the information-centric QA in the RLSCs of DW. Due to the interdependent nature of epistemic uncertainties, the IPMs implemented in response to one epistemic uncertainty could also impact on others. None of the previous studies, to date, have attempted to investigate all these areas; thus, investigating information processing for QA in RLSCs of DW is important for the above reasons.

With reference to the discussion above, some gaps in the extant literature are evident, as summarised below, which were addressed through the current research:

Firstly, no empirical insights establish how process, people, policy and technology contribute to QA in RLSCs of DW

Secondly, unrecognised epistemic uncertainties lead to IPNs and corresponding IPMs for QA in RLSCs of DW

Thirdly, no investigation has been undertaken on information processing for QA in RLSCs of DW.

Chapter 2 discusses each of these knowledge gaps in the literature in detail. With these knowledge gaps, the main thrust of the current study is to develop and empirically validate an information processing model by identifying and assessing the interrelationships of epistemic uncertainties for QA in RLSCs of DW.

1.3 Research Aim and Objectives

In line with the above-mentioned knowledge gaps, the aim of this study is:

> To develop and empirically validate an information processing model by identifying and assessing the interrelationships between epistemic uncertainties for quality assurance (QA) in reverse logistics supply chains (RLSCs) of demolition waste (DW).

The following objectives directed the research pathway towards accomplishing the above-mentioned aim:

OB.1: To establish how process, people, policy and technology contribute to quality assurance in reverse logistics supply chains of demolition waste

OB.2: To identify epistemic uncertainties that lead to information processing needs and corresponding information processing mechanisms for quality assurance in reverse logistics supply chains

OB.3: To develop an information processing model for quality assurance in reverse logistics supply chains and to empirically validate the model

OB.4: To assess the applicability of the information processing model for quality assurance within real-world reverse supply chain contexts

1.4 Research Questions

Previous studies mentioned that once objectives were developed, the next step was to operationalise them by transforming them into research questions (Frechette et al. 2020; Parraguez 2015; Reynolds & Guest 2015). Frechette et al. (2020) stated: 'the research questions will flow from the objective and break down the phenomenon to be examined into smaller parcels' (p. 6). As revealed by Sandberg and Alvesson (2011), gap spotting is the most dominant way of constructing research questions which could be done via three basic modes: confusion, application and neglect spotting. In confusion spotting, the research questions are constructed to point out a particular confusion in the existing literature, while in application spotting, the research questions signpost the absence of a particular theory or perspective in the area of the research. Neglect spotting is the most prevalent mode of constructing research questions, in which the questions dignify a topic or an area that is overlooked, under-researched or lacks empirical support. The current study has four objectives (see Section 1.3), developed based on three knowledge gaps (see Section 1.2), as shown in Figure 1.1. The first objective (OB.1) was developed from a knowledge gap that spotted an area lacking empirical support, while the remaining three objectives were developed from knowledge gaps that indicated overlooked areas in the extant literature related to the RLSCs of DW. Therefore, as shown in Figure 1.1, four sub-research questions were constructed in the current study as per the neglect gap spotting mode explained by Sandberg and Alvesson (2011).

These sub-research questions were then consolidated into one primary research question as follows:

> How is information processed, in response to the epistemic uncertainties that lead to information processing needs, for quality assurance in reverse logistics supply chains of demolition waste?

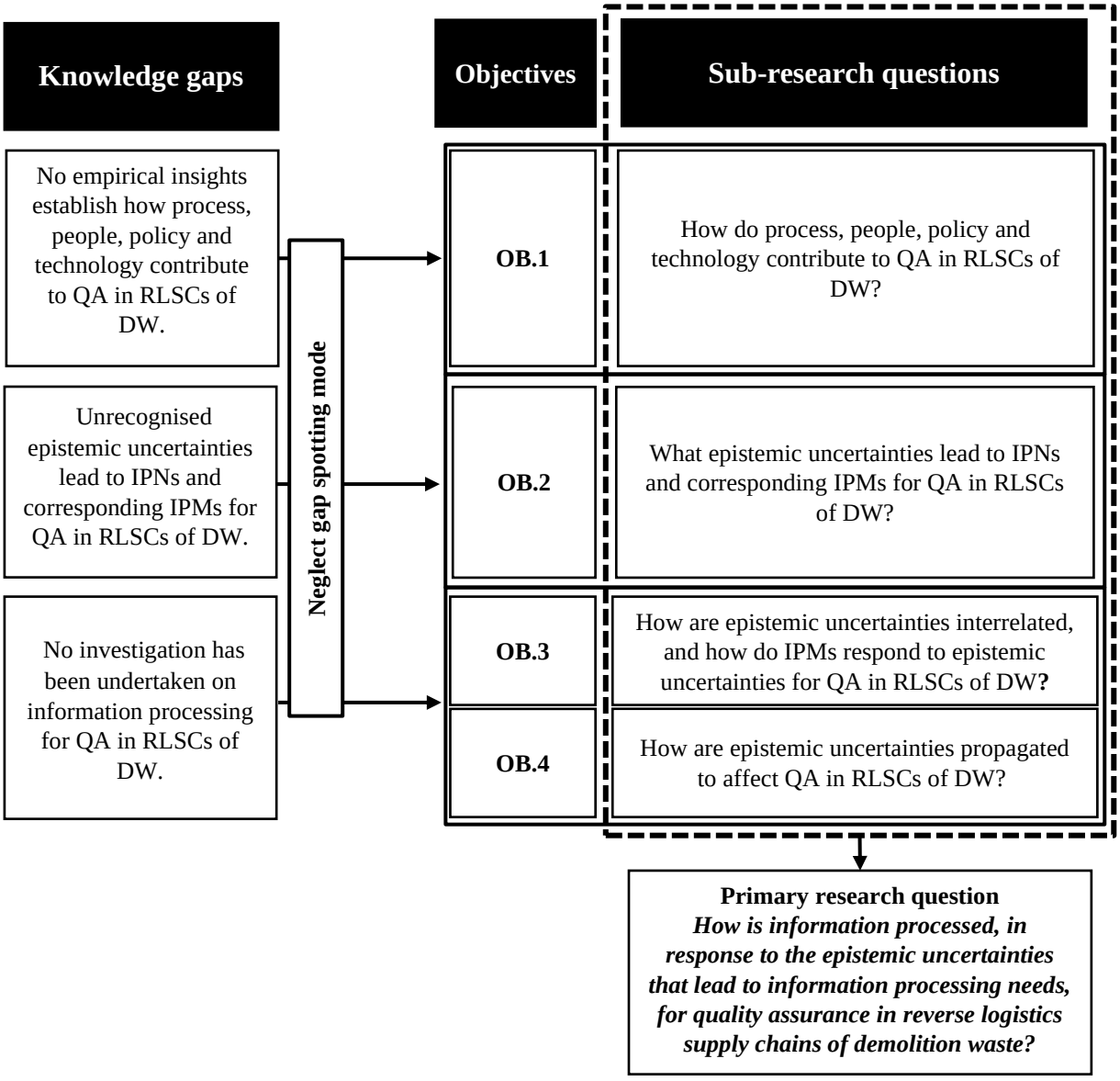


Figure 1.1. Knowledge gaps mapped with research objectives and questions

1.5 Overview of Research Methodology

This study employed a mixed-methods design involving qualitative and quantitative research methods to collect, analyse and interpret data to answer the research questions.

The study was conducted in four sequential phases: (i) semi-structured interviews; (ii) structured interviews; (iii) a focus group discussion; and (iv) case studies.

In the first phase, an exploratory study was conducted using semi-structured interviews with internal and external stakeholders in RLSCs of DW. The data collected from the semi-structured interviews were analysed using directed content analysis. This qualitative phase sought to establish how process, people, policy and technology contribute to QA in RLSCs of DW. Furthermore, epistemic uncertainties that lead to IPNs and corresponding IPMs for QA in RLSCs were identified through semi-structured interviews in this first phase of data collection. The second phase followed a quantitative approach by conducting 20 structured interviews with experts in the DW management sector, representing the building dismantling and on-site processing phase and the off-site waste processing phase. The purpose of conducting structured interviews was to develop an information processing causal map for QA in RLSCs of DW. Nine logical tests with two statistical values, namely, ‘average’ and ‘skewness’ (Nasir, McCabe & Hartono 2003), were used to compute the conditional dependencies in the model between: (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and the performance measurement criterion (i.e., QA); and (iii) IPMs and epistemic uncertainties. In this phase, the developed causal map was transformed into a Bayesian belief network (BBN)-based conceptual information processing model using the principles of the causal mapping approach. A focus group discussion was organised in the third phase with five experts in the DW management sector to empirically validate whether the BBN-based conceptual information processing model for QA was developed correctly, including all its variables and relationships, before introducing it to the probability elicitation. With the focus group discussion findings, the conceptual information processing model was modified to be ready for application in the real-world context of RLSCs of DW. This model presents the logical sequence of epistemic uncertainties that lead to IPNs and IPMs for QA in RLSCs of DW. Therefore, in the last phase, the modified model was applied in two cases in the construction industry. During this phase, the BBN analysis was conducted as both within-case and cross-case analyses using probabilistic inferences.

1.6 Scope and Limitations of the Study

The current study focused only on RLSCs of DW. This initial boundary of the study was established owing to the necessity of enhancing the information-centric QA of RLSCs of DW, closing its inherent information deficiency (Jayasinghe, Chileshe & Rameezdeen 2019; Wijewickrama et al. 2021a). Furthermore, the study was limited to the South Australian (SA) context; thus, all data collection methods were conducted as they related to DW management in SA. In fact, SA is the leader in CDW management in Australia (Green Industries South Australia [GISA] 2020). It has been found that SA is the jurisdiction that has made the highest contribution to the 67% CDW recycling rate in Australia (Pickin et al. 2018; Zhao, X et al. 2022). The diversion rate of CDW in SA was 91.4% in 2020, and the state is expected to achieve a 95% diversion rate by the end of 2025 (GISA 2020). Therefore, conducting this study within such a context is ideal for obtaining a valuable stream of knowledge regarding information processing for QA due to the state's innovativeness and experience in CDW management.

The RLSC of DW is complicated as, in most cases, it encompasses more than one internal stakeholder representing different organisations with varied interests (Schamne & Nagalli 2016). Generally, demolition organisations are accountable for dismantling, collection, on-site sorting and transportation of salvageable waste to an off-site materials recovery facility (MRF), while transferring the contaminated waste and waste with no value to authorised landfill sites. However, due to limited continuous job assurance, demolishing organisations, at times, employ sub-contractors who specialise in soft stripping, asbestos management and transportation. On the other hand, waste processors are entitled to carry out waste processing and, in most cases, the marketing of reprocessed products (Jayasinghe, Chileshe & Rameezdeen 2022). The waste which cannot be recovered is diverted to be dumped at landfill sites or appropriate dumping sites; thus, this is also an operational phase appearing under the definition of the RLSC of DW. However, the problem under investigation in the current study is primarily the quality of reprocessed products. Therefore, the study only considers a series of phases of an RLSC, from the dismantling of a building to the secondary market, excluding residue disposal from the study's scope. As two organisations were involved, the current study considered the RLSC of DW to be in a dyadic configuration. Furthermore, from an OIPT perspective, Daft and Lengel (1986) mentioned that organisations process information to reduce not only epistemic uncertainties but also equivocality, a situation

in which multiple and conflicting interpretations are due to information messiness. However, the current study only considered information processing for epistemic uncertainties due to the issue of information deficiency in RLSCs of DW which is recurrently outlined as an issue in the body of extant literature (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b; Wijewickrama, Rameezdeen & Chileshe 2021; Wu, Z et al. 2022).

1.7 Significance of the Study

Over the last few decades, interest in RLSCs of DW has grown following the upsurge of detrimental issues affecting the environment, the economy and society due to the accumulation of DW accompanying rapid urbanisation (Patel, Shrivastava & Patel 2021; Yu, B et al. 2019). Even though many areas of the construction supply chain received attention, the RLSC of DW is one of the areas that received the least amount of attention (Pushpamali et al. 2021; Trochu, Chaabane & Ouhimmou 2020). Therefore, the RLSC of DW could be considered an emerging area yet to be explored. Despite empirical studies identifying the barriers to implementing RLSCs of DW (Chileshe et al. 2015; Correia et al. 2021; Jayasinghe, Chileshe & Rameezdeen 2022), only a few have attempted to overcome these barriers (Correia et al. 2021). Several previous studies highlighted that the issues relating to QM efforts and information deficiency in RLSCs of DW were interdependent and related (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021a; Xia & Bakker 2014). However, none of the previous studies undertook an in-depth investigation of this aspect. The current study aims to bridge this substantial gap in the literature by developing an information processing model for QA in RLSCs of DW.

Along the path undertaken to develop this model, the current study contributed to the existing knowledge, firstly, by empirically establishing how process, people, policy and technology contribute to QA in RLSCs of DW. Secondly, the study identified the epistemic uncertainties which lead to IPNs for QA and the corresponding IPMs that could be implemented in response to these epistemic uncertainties. Thirdly, the study investigated the cause-and-effect relationships of the epistemic uncertainties between inter- and intra-phases of an RLSC of DW. Moreover, the appropriate IPMs in response to each epistemic uncertainty were determined by developing cause-and-effect

relationships between epistemic uncertainties and IPMs. Finally, these interrelationships facilitated the development of the BBN-based conceptual information processing model for QA. Internal stakeholders could use this model to understand how information should be processed in their respective supply chains in response to the epistemic uncertainties that lead to IPNs for QA.

As for its theoretical contributions, to the best of the researcher's knowledge, this study is one of the first investigations performed to provide a holistic understanding of information processing for QA through the OIPT's theoretical lens. The current study advances previous studies on RLSCs of DW that outlined how information deficiency severely impacts on quality efforts (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021a; Xia & Bakker 2014). It provides a concrete understanding of how this happens (i.e., epistemic uncertainties) and how internal stakeholders cope with these deficiencies (i.e., with IPMs). As another important initiative, the study found that the epistemic uncertainties propagate and cause the creation or compounding of epistemic uncertainties in the same or following phase in RLSCs of DW. Subsequently, this interrelated configuration of epistemic uncertainties creates a systemic effect on the QA in RLSCs of DW. Accordingly, the current study contributes to the OIPT-related literature by determining that epistemic uncertainties do not exist independently; instead, they form cause-and-effect relationships. Furthermore, the study establishes that, due to the interdependent nature of epistemic uncertainties, to successfully evade information deficiencies, as far as practicable, most IPMs should be implemented in response to those epistemic uncertainties that appear as root causes.

1.8 Summary of Findings

As explained in Section 1.4, the study followed an exploratory sequential mixed-methods approach to accomplish its aim. Through conducting 30 semi-structured interviews in the first phase of data collection, the study established that QA is not a solitary effort in RLSCs of DW; instead, it is an integrated approach comprising the four aspects of process, people, policy and technology. The contribution of these aspects for QA was separately discussed during the following phases of RLSCs of DW: building dismantling and on-site processing and off-site waste processing. During the same data collection phase, 16 epistemic uncertainties for QA were identified,

comprising six macro-level, two meso-level and eight micro-level uncertainties. The macro-level uncertainties evolved due to lapses in the information-centric influence strategies of external stakeholders of RLSCs of DW. Thus, they were beyond the control of internal stakeholders in RLSCs of DW. Moreover, the meso-level uncertainties stemmed from the supply chain, while the micro-level uncertainties arose from the interactions of each internal stakeholder organisation. Therefore, those uncertainties were within the realm of control of the particular internal organisation or its supply chain partners. Furthermore, the study found 15 IPMs that could be implemented in response to the epistemic uncertainties. Some IPMs were common to both demolishers and waste processors, while others were specific. An interesting finding in this phase was that all epistemic uncertainties and IPMs represented aspects of the quality assurance system (QAS): process, people, policy and technology. Therefore, the current study put forward the proposition that these aspects of the QAS are accountable for creating the information-centric environment needed for them to be integrated for the purpose of QA in RLSCs of DW.

Through conducting 20 structured interviews during the second phase of data collection, a BBN-based conceptual information processing model was developed, comprising 45 cause-and-effect relationships between: (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and the performance measurement criterion (i.e., QA); and (iii) IPMs and epistemic uncertainties. A focus group discussion was conducted in the third data collection phase to empirically validate the BBN-based conceptual information processing model for QA. From this phase, 15 new relationships between epistemic uncertainties were added to the model while two links between IPMs and epistemic uncertainties were deducted. In this conceptual information processing model, the macro-level uncertainties appeared at the bottom of the model, indicating that they caused the remaining meso- and micro-level uncertainties. Additionally, all the IPMs were positioned at the most appropriate epistemic uncertainties in the model so that the effect of an IPM in response to a particular epistemic uncertainty could also be exerted on the remaining epistemic uncertainties linked to the earlier uncertainty. In the last data collection phase, the empirically validated conceptual model was applied in two cases to assess the model's applicability in analysing information processing for QA. The study found that, compared to RLSCs with large-scale organisations, RLSCs with small and medium-scale organisations were more vulnerable to macro-, meso- and micro-level

uncertainties for QA. Of all the epistemic uncertainties, RLSCs of DW were most susceptible to ‘mixed waste received from demolishers’ which was a waste processor’s meso-level uncertainty. Furthermore, the current study found that if many IPMs were available, implementing them in combination could successfully respond to epistemic uncertainties.

1.9 Structure of the Thesis

This thesis comprises nine chapters, with Figure 1.2 outlining a map between these chapters and the research objectives. Chapter 1 initiates the thesis by presenting the research background, problem statement, aim, objectives, method of study, scope and limitations, and the chapter breakdown. Chapter 2 reviews the existing literature on the RLSC of DW and its significant barriers, basic QM approaches and principles and the OIPT’s theoretical underpinnings. This chapter further elaborates on the importance of information processing for QA in RLSCs of DW. Chapter 3 outlines the research methodology of the study, including the research design, data collection and analysis methods, and ethics considerations. Chapter 4 explains the findings from the semi-structured interviews which accomplish Objectives 1 (OB.1) and 2 (OB.2). Chapter 5 outlines the findings of the structured interviews which advocate the development of the BBN-based conceptual information processing model for QA in RLSCs of DW. Chapter 6 discusses the findings of the focus group discussion in which the BBN-based conceptual model developed in Chapter 5 is empirically validated. Chapters 5 and 6 together fulfil the study’s Objective 3 (OB.3). Chapter 7 presents the findings of within-case and cross-case analyses undertaken to assess the applicability of the BBN-based information processing model for QA within two real-world reverse supply chain contexts, fulfilling the study’s Objective 4 (OB. 4). Chapter 8 discusses the findings of the study, followed by Chapter 9 which outlines the conclusions drawn from the findings, including the study’s limitations and future research directions.

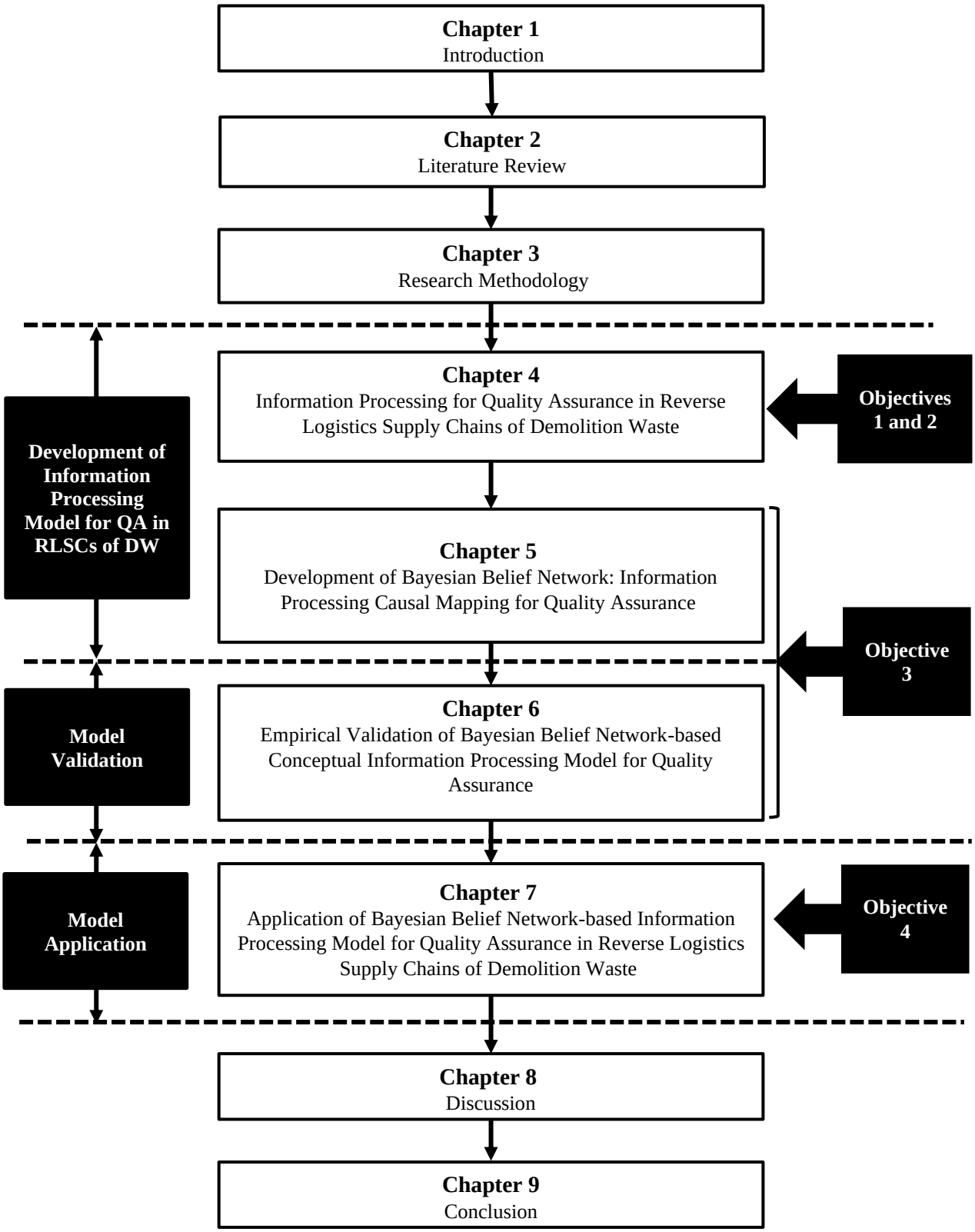


Figure 1.2. Structure of the thesis

1.10 Concluding Remarks

This chapter provided a brief introduction to this doctoral study. The rationale for undertaking the research was addressed, justifying the study's aim of developing an information processing model for QA in RLSCs of DW. Four sub-research questions were constructed, as per the neglect gap spotting mode, from which the study's four objectives were established. The method to achieve each objective was then briefly discussed. The study's scope and limitations, and its significance were then presented, followed by a summary of the key research findings. The chapter concluded by outlining the structure of the thesis. The next chapter reviews the existing literature related to the study area to affirm the knowledge gaps that the study seeks to address.

2 Literature Review

2.1 Introduction

The previous chapter introduced the research area under investigation and the rationale for the study. This chapter reviews the related empirical and theoretical knowledge. The chapter first introduces an RLSC of DW and provides an overview of the supply chain phases. The chapter establishes that the poor quality of reprocessed products and the issue of information deficiency are significant and interrelated barriers that impede successful RLSC adoption. When the four aspects of the QAS, namely, process, people, policy and technology, are underperforming, the useful information required is not processed, creating epistemic uncertainties for QA in RLSCs of DW. The chapter then provides an overview of the theoretical perspectives of OIPT to form a basis for justifying the need for an information processing model for QA in RLSCs of DW. Finally, the chapter concludes with a briefing on the gaps in the body of knowledge identified through the literature review.

2.2 Reverse Logistics Supply Chains (RLSCs)

Kroon and Vrijens (1995) introduced RL as a logistic management skill that comprises reducing, managing and disposing of hazardous and non-hazardous waste. By definition, RL means:

> The process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. (Rogers & Tibben-Lembke 1999, p. 2)

As further described by Rogers and Tibben-Lembke (1999), RL is a process in which organisations try to be environmentally efficient by recycling, reducing and reusing waste materials. It is primarily about optimising the flow of products and related information from the point of consumption to their origin to regain their utmost economic and biological value while reducing the eventual quantities of waste in

landfill (Rogers & Tibben-Lembke 1999). Subsequently, an RLSC is defined as a series of activities that promote the planning, implementation and control of the optimisation process of a product and information flow from consumption to origin (Zhong & Zhang 2018). Therefore, irrespective of the industry, the RLSC exceeds the contemporary forward supply chain (FSC) and enables the formation of a closed-loop supply chain (CLSC).

2.3 RLSCs of Demolition Waste (DW)

Construction and demolition waste (CDW) is produced throughout the life cycle of a construction project (Jin et al. 2017; Wu, Z et al. 2014). The waste generated through demolition activities is more than 70% of the total CDW (Chen, K et al. 2021; Wu, Z, Yu & Shen 2017). This has led to a growing trend of using DW as landfill material and, in some cases, illegally dumping it in vacant lots (Bravo et al. 2015a; Yu, B et al. 2019). Improper management of DW has created negative impacts on the environment, the economy, public health and society (Chinda et al. 2018; Yeheyis et al. 2013; Yu, B et al. 2019). Findings from prior studies have shown that most DW destined for landfill or dumping sites, including materials like timber and metal, has mature secondary markets (Caldera, Ryley & Zatyko 2020; Poon et al. 2004). Therefore, it is imperative to manage DW efficiently and effectively to reduce the volume of dumped waste (Bravo et al. 2015b; Wu, Z, Yu & Shen 2017).

In this regard, the RLSC has been recognised as an effective solution to manage the increasing amounts of DW generated by the construction industry (Jayasinghe, Rameezdeen & Chileshe 2022; Rahimi & Ghezavati 2018). When reviewing the literature in the current study, a clear definition of the RLSC exclusive to DW management in the construction industry was not found. Instead, the concept and interchangeable usage of terms, such as the RLSC, green logistics and waste management, demonstrated ambiguity in the existing literature (Hosseini et al. 2014). In more specific terms, the study of the RLSC in the Brazilian construction industry by Nunes, Mahler and Valle (2009) defined the RLSC as:

> How the area of business logistics plans, operates and controls the flow of logistics information corresponding to the return of post-sale and post-consumption of the goods to the productive cycle through reverse distribution channels, adding the value of various types to them: economic, ecological, legal, logistical, corporate image, etc. (p. 3717)

Previous studies revealed that RLSCs of DW yield environmental, economic and social benefits to the construction industry (Brandão et al. 2021b; Jayasinghe, Rameezdeen & Chileshe 2019). The construction industry is concerned with minimising the aggregate quantity of waste generation and resource consumption to pave the way to a sustainable construction platform (Ajayi et al. 2016; Maury-Ramírez, Illera-Perozo & Mesa 2022; Ossa, García & Botero 2016). Both these targets are facilitated by RLSCs of DW which endeavour to recover maximum value from used materials while keeping them in a CLSC (Jayasinghe, Rameezdeen & Chileshe 2019).

As it involves a complicated process, an RLSC of DW has a series of operational stages. Using manufacturing industry experience, many researchers have conceptualised the RLSC in the construction industry (Hosseini et al. 2013a, 2014). However, a difference is apparent between the two RLSC processes in the manufacturing and construction industries. The difference is that in the construction industry, a significant portion of waste enters the process at the EoL of a structure (Chen et al. 2021; Wu, Z, Yu & Shen 2017). In contrast, in the manufacturing industry, these products can enter the process at different FSC stages (Hosseini et al. 2014).

Figure 2.1 illustrates the sequential stages in an RLSC of DW. The blue arrows indicate the RLSC of DW. As shown in Figure 2.1, integration between the series of stages indicates the flow of logical relationships in an RLSC of DW (Tennakoon, Rameezdeen & Chileshe 2022). The authors further mentioned that this configuration explains how materials, information and finance flow within an RLSC of DW. As an RLSC of DW constitutes many stages, in most cases, many business entities with different interests are involved in the process (Schamne & Nagalli 2016; Wijewickrama et al. 2021a). In general, demolition companies and sub-contractors with whom demolishers are working are together accountable for dismantling, collection, on-site sorting and transportation of salvageable waste to an off-site MRF while transferring the contaminated waste and waste with no value to authorised landfill sites or dumping sites (van den Berg, Voordijk & Adriaanse 2020; Wijewickrama et al. 2022). On the other hand, waste processors are entitled to carry out waste processing and, in most cases, the marketing of reprocessed products (Wijewickrama et al. 2022). Thus, in general, two organisations are involved in each of the building dismantling and on-site processing and off-site processing phases in an RLSC of DW, with these organisations having contrasting cultures, interests, capacities and vulnerabilities.

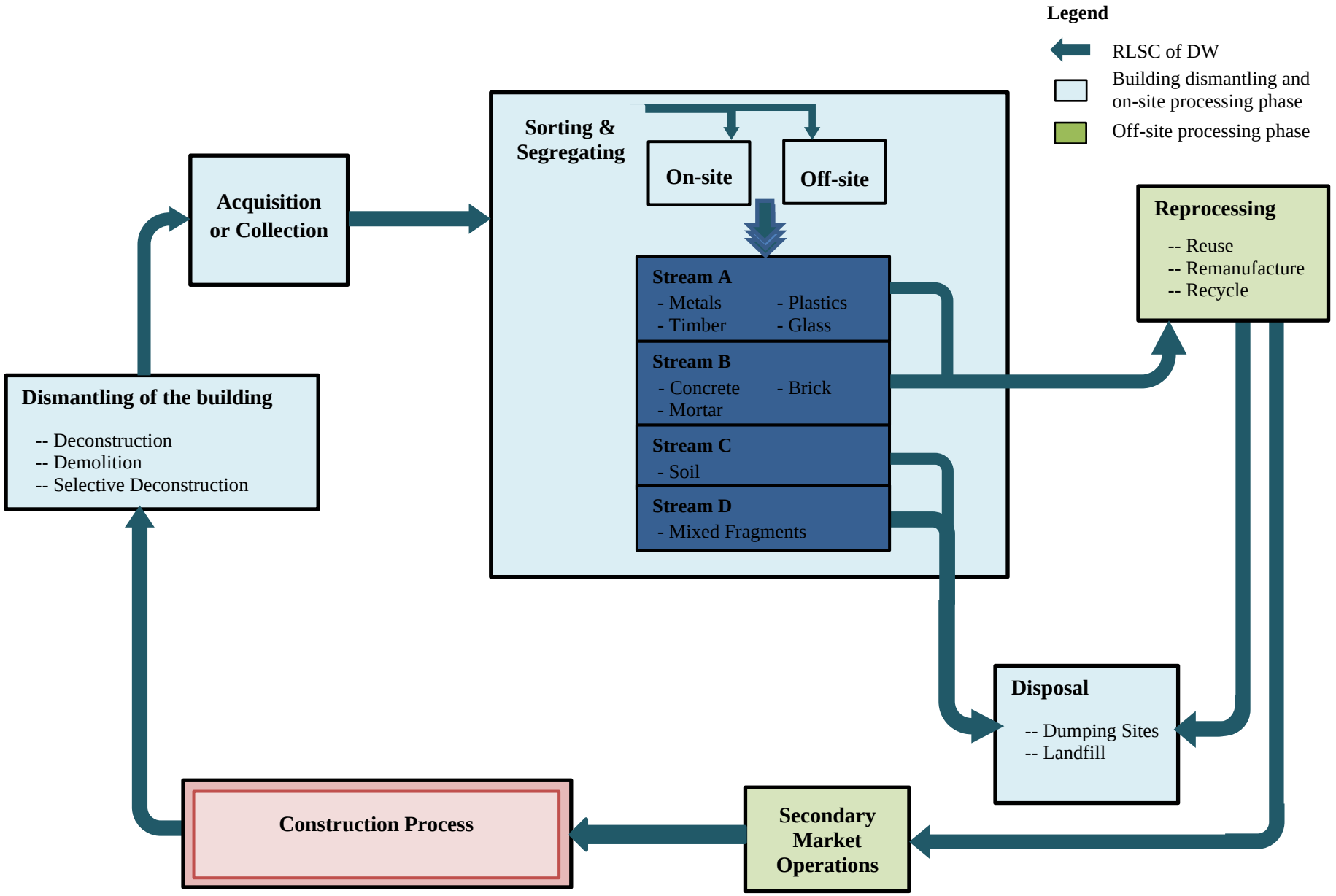


Figure 2.1. Reverse logistics supply chain (LSC) of demolition waste (DW)

(Source: Adapted from Hosseini et al. 2013b, 2014; Huang, WL et al. 2002; Zheng, L et al. 2017)

Consequently, to establish the context of the current study, the RLSC of DW is considered to be a supply chain with a dyadic configuration. Each phase in this dyad is explained in detail in Figure 2.1.

2.3.1 Building dismantling and on-site processing phase

As shown in Figure 2.1, an RLSC of DW is initiated with the dismantling of a building. Subsequently, the dismantled waste is collected, sorted and segregated before being introduced to reprocessing. This stage in an RLSC of DW is imperative as the choice of dismantling technique decides the quantity and quality of salvageable waste of a building that could be recovered through reprocessing (O'Grady et al. 2021). Until the 1950s, buildings at the EoL phase were dismantled using simple methods like deconstruction by hand or simple equipment (Roodman, Lenssen & Peterson 1995). Due to technology and physical infrastructure developments, two types of alternative dismantling techniques are currently prevalent in the construction industry: deconstruction and demolition (Aidonis 2019). The word 'demolition' means dismantling a building using explosive or non-explosive mechanical methods within a short period. The most common method of demolition prevailing in the current construction industry is the 'top-down' method (Kang et al. 2022). As the name suggests, top-down demolition begins from the roof then proceeds to the foundation in a floor-by-floor method (Poon, Yu & Ng 2001). This dismantling method is being heavily criticised as highly destructive and complex while, at the same time, increasing the piles of debris diverted to landfill (Hoang et al. 2022; Saghafi & Teshnizi 2011). On the other hand, deconstruction means safely dismantling the building/structure by doing less damage to the salvageable waste (Queheille, Taillandier & Saiyouri 2019). In simple terms, deconstruction is the reverse of the construction process. This means that, in deconstruction, a building is disassembled piece by piece, starting from the last building component placed during construction. Due to this systematic approach, deconstruction generates a plethora of advantages. For instance, it is a method that reduces environmental pollution by reducing carbon emissions, waste in landfill, probable health hazards and associated disturbances (Akinade et al. 2017; Queheille, Taillandier & Saiyouri 2019). However, the method is criticised as expensive, time consuming and labour intensive (Akinade et al. 2017; Poon, Yu & Ng 2001). In practice, selective deconstruction, a combination of deconstruction and demolition, has attracted the

immediate attention of most practitioners due to its practicability, economic viability and productive outcomes, thus eradicating all the drawbacks inherent within demolition and deconstruction (Hoang et al. 2022). Consequently, these authors further emphasised that selective deconstruction is considered the most recommended and sustainable dismantling approach in the construction industry.

After dismantling, the extracted salvageable waste is collected, sorted and segregated, as shown in Figure 2.1. These stages are also crucial to enhance materials recovery efficiency, better quality of salvageable waste (i.e., with low contamination), lower rates of waste disposed of in landfill and reduced environmental impacts (Ruiz, Ramón & Domingo 2020). The effectiveness of sorting depends on the dismantling method and the sorting location (Gołębiewski et al. 2013). The waste collected after dismantling is heterogeneous and includes different compositions of soil, gravel, pieces of concrete, ceramics, bricks, tiles, plaster, sand and stones (El-Haggar & Samaha 2019). Thus, it is essential that preliminary inspections of this waste is carried out as much as possible before initiating sorting (Lu & Yuan 2012). Generally, the sorting can be done on site or off site (Jiménez-Rivero & García-Navarro 2016). On-site sorting is highly recommended as it increases the recovery amount of salvageable materials while reducing the possibility of materials ending up in landfill. In contrast, in off-site sorting, contractors send the dismantled waste from construction sites to off-site sorting facilities for sorting and segregation (Hossain, Wu & Poon 2017). The most common sorting method practised by industry is off-site sorting, despite on-site sorting being mostly applauded (Hossain, Wu & Poon 2017; Poon, Yu & Ng 2001). The reason is that on-site sorting requires a considerable amount of site space, high management commitment and significant labour contribution, all of which undeniably increase the operational cost. During sorting and segregation, the dismantled waste is classified as streams A, B, C and D (Huang, WL et al. 2002; Zheng, L et al. 2017), as shown in Figure 2.1. Only the types of waste in streams A and B are introduced for further reprocessing, while streams C and D are diverted to landfill or appropriate dumping sites.

Building dismantling and on-site processing are mostly performed by one specific organisation (van den Berg, Voordijk & Adriaanse 2020; Wijewickrama et al. 2022), referred to as a ‘demolisher’ in the current study. Once the salvageable waste is collected, sorted and segregated, it is transported to an MRF for reprocessing. Table 2.1

summarises the operations undertaken within this phase of an RLSC of DW by a demolisher.

Table 2.1. Operations within the building dismantling and on-site processing phase

Phase in the RLSC	Operations within the phase	References
Building dismantling and on-site processing	**Preliminary planning** • Preparing demolition drawings • Demolition execution plan development	Cha et al. (2012); del Río Merino, Gracia & Azevedo (2010)
	Demolition execution • Disconnect all services • Site preparation and ensure health and safety measures • Soft stripping (careful removal of higher value salvageable items like doors, windows, air conditioning units and timber items) • Dismantling (deconstruction or demolition)	Kourmpanis et al. (2008) Chileshe, Jayasinghe & Rameezdeen (2019)
	On-site sorting and segregation • Waste is separated at the site as streams A, B, C and D.	Huang, WL et al. (2002); Zheng, L et al. (2017)

2.3.2 Off-site waste processing phase

According to previous studies, the available reprocessing alternatives in the construction industry are reuse, remanufacturing, recycling and down-cycling (Chinda 2017; Nasir et al. 2017). However, remanufacturing is not implemented much in construction waste reprocessing (Chinda 2017). As specified by Schultmann and Sunke (2007), reprocessing methods, such as repairing, refurbishing and cannibalisation, are also implemented in RLSCs in construction. Reuse and recycling are the most commonly adopted alternatives for reprocessing (Chen, Z et al. 2016). Reuse is preferable to reprocessing as it consumes less time, cost, energy and raw materials while generating minimal environmental pollution (Akanbi et al. 2019; Chinda & Ammarapala 2016; Hosseini et al. 2015). For instance, if a facility is deconstructed, some materials, such as contaminated aggregates, could be directly used as substitutes for natural coarse aggregates in concrete without further reprocessing (Nagataki et al. 2004). However, this is not always feasible as deconstruction is not commonly practised when dismantling buildings. In this case, recycling is the most popular option, especially for reprocessing concrete, steel and timber (Bustillo Revuelta 2021; Saghafi & Teshnizi 2011).

Off-site reprocessing in an MRF differs with the size of the business and its resources. The process generally begins with loading incoming clean waste onto the feed hopper (Mah, Fujiwara & Ho 2018). Waste pickers manually sort the non-acceptable materials, with the waste going through varied screens before being sent into the jaw crusher. The waste materials pass through the primary crusher, then under a magnetic belt to screen out the scrap metal before being introduced to the first cone crusher, where the waste materials are further crushed into smaller sizes. The waste materials are next screened via vibrating screens where oversized materials are directed into the second cone crusher. Finally, the waste materials that cannot be reprocessed are directly disposed of in landfill without further reprocessing. This is the typical process undertaken inside an MRF for off-site waste processing.

After reprocessing, all final products are physically transferred to potential secondary markets (Ratnasabapathy, Alashwal & Perera 2021). Alternatively, the reprocessed products are introduced to the FSC in this step. In this stage, the products are tested against technical specifications or standards before they are transported to secondary markets, thus ensuring that the quality of the final products fulfils end-user requirements (Çorbacıoğlu & Laan 2013; Shooshtarian et al. 2020). Shooshtarian et al. (2020) highlighted that if product certification was awarded to end-users after testing the reprocessed products, the acceptance and adoption of these materials could be increased in the construction industry. According to Jayasinghe, Chileshe and Rameezdeen (2019), the marketability of reprocessed products depends on the quality of dismantling, effective sorting and segregation, appropriate reprocessing, the economic value of the products and the maturity of the markets. Generally, reprocessed products, such as concrete, bricks, glass and timber, have a high market value (Owolabi et al. 2014). Despite the significance of this stage in promoting reprocessed products to the secondary market, appropriate strategies, research and development are lacking for generating a market-oriented RLSC in construction.

In general, off-site waste processing and marketing of reprocessed products are performed by one specific organisation (Wijewickrama et al. 2022), referred to as a ‘waste processor’ in the current study. The waste processor diverts the unusable DW that does not have value to residue disposal sites (Tennakoon, Rameezdeen & Chileshe 2022). However, this option is the least supported as it deviates from the primary purpose of implementing RLSCs which is to recover maximum value from salvageable

waste. The preferable way to dispose of residues is to landfill sites rather than illegal dumping (Mihai 2019; Ogunmakinde, Sher & Maund 2019). Even though landfill sites are more desirable than illegal dumping, their adverse effects on the environment and society make them unsustainable (Vaverková 2019). The problem under investigation in the current study is primarily the quality of reprocessed products. Therefore, the study's scope only considers the series of stages of RLSCs from dismantling to the secondary market and excludes residue disposal.

2.4 Barriers to RLSC Adoption in the Construction Industry

Despite the growth of the RLSC in the construction industry, many barriers inhibit its successful adoption. According to Hosseini et al. (2013a) and Hosseini et al. (2015), organisational and operational (industry-specific) barriers confront RL adoption in the construction industry. Based on the SA construction industry, Chileshe et al. (2015) highlighted that, in addition to organisational and operational barriers, social and environmental barriers hinder successful RLSC adoption in the construction industry. Hosseini et al. (2014) indicated that the key barriers to RL implementation are due to the complex and fragmented nature of the construction industry supply chain. These authors emphasised that operational barriers can be imposed due to the governing business environment of the industry and the nature of the construction products and activities. In a recent study, Correia et al. (2021) found infrastructure, organisational, social, management, government policies and financial barriers to adopting RL in the construction industry. Table 2.2 summarises these barriers based on the findings of these previous studies. In the general context, for RL adoption to begin, it needs substantial physical and financial resources and individual efforts (Wijewickrama et al. 2022). However, the shortage of these resources impedes successful adoption. Congruently, when considering the organisational barriers listed in Table 2.2, it is understandable that most have evolved due to the scarcity of initial commitment. However, as per Table 2.2, most barriers to implementing RL are external to the organisations; thus, they are not easy to control (Brandão et al. 2021b). Internal organisational barriers could be managed by a strategic management decision-making system (Hosseini et al. 2014); however, it is important to highlight that operational and external environmental barriers form a substantial hurdle to implementing RL in the construction industry. Therefore, it is crucial that these barriers be managed cautiously to successfully adopt RL in the construction industry.

Table 2.2. Barriers to RLSC adoption in the construction industry

		Barriers
	Organisational barriers	• High initial cost and labour cost • Time-consuming nature • Risk (health and safety; financial), potential liabilities and uncertainties • Restrictive organisational policies • Lack of awareness • Less attention to knowledge management perspectives and potential advantages • Less manpower and qualified people • Lack of infrastructure and managerial support • Organisational cultural attitudes
Operational barriers	Environmental-based barriers	• Lack of industrial support and infrastructure (storage areas and other facilities) • Competitive pressure • Lack of recovery facilities • Lack of technological advancement • Lack of a systematic approach to RL implementation • Low quality of salvaged and used items • Lack of proper pricing strategy • Information deficiency, lack of knowledge and information sharing • Adverse business culture • Immaturity of markets for salvaged materials • Low cost of disposal of materials and landfill use • Ineffective cooperation between the parties involved and with information sharing • Impact of a large number of stakeholders
	Barriers based on the nature of the product	• Long life cycle of the building and change of owner • Tight scheduling of the project • Uniqueness (immobility, size, complexity, containing hazardous materials, etc.) and fragmented nature of the industry • Existing buildings do not facilitate deconstruction • Uncertainty associated with availability of resource points (buildings)
	External environmental-related barriers (Social)	• Low quality of reprocessed products • Lack of support from the government, regulatory bodies and non-governmental organisations (NGOs) • Unaffordable and inappropriate regulations and policies • Problems in issuing licences and approvals (especially for deconstruction and use of salvaged materials)

(Source: Chileshe et al. 2014; Chileshe et al. 2015; Correia et al. 2021; Hosseini et al. 2013b, 2014; Hosseini et al. 2015; Rameezdeen et al. 2015)

2.4.1 'Poor quality of reprocessed products' as a significant barrier to RLSCs of DW

Despite significant efforts to promote RL in the construction industry, the issue of poor-quality reprocessed products continues to inhibit its adoption in practice (Wijewickrama et al. 2021a). Due to this issue of quality, construction practitioners are hesitant to use reprocessed products in their projects (Chileshe et al. 2015). This is a serious issue for RLSCs of DW: if the market does not accept the products, the DW management industry is not sustainable. According to Pushpamali, Agdas and Rose (2020), the

overall quality of reprocessed products should be at least equal to the quality of virgin products for them to be accepted for new construction. However, end-users have a negative perception that the quality of reprocessed products is less than that of virgin materials owing to the stigma attached to the terms ‘recycled’ or ‘reused’ materials (Feng et al. 2019; Huang, B et al. 2018; Pushpamali, Agdas & Rose 2020; Schamne & Nagalli 2016; Sobotka & Czaja 2015). For instance, Feng et al. (2019) found that even after RCAs were mixed with virgin materials for quality improvement, end-users were reluctant to use them owing to the ‘recycled’ label. Extending beyond this perception, industry practitioners have also experienced the inferior quality of reprocessed products compared to that of virgin materials (Chileshe et al. 2015; Chileshe et al. 2016; Huang, B et al. 2018). Given this point, Chileshe et al. (2015) found in their quantitative study that the most crucial barriers to adopting RL in the construction industry were drawn from the ‘operational category’ (see Table 2.2). Of all barriers, the most significant was hesitation of industry practitioners to incorporate salvaged materials in their future projects due to the poor quality of reprocessed products. On this note, the inferior quality of reprocessed products is criticised globally (Chileshe et al. 2014; Wibowo et al. 2022), becoming the primary constraint restricting the popularity of reprocessed products (Chileshe, Rameezdeen, & Hosseini 2016; Wijewickrama et al. 2021a).

Previous studies identified quality issues in reprocessed products, especially in RCAs. Accordingly, several quality issues have occurred in RCAs due to their components, such as asphalt, gypsum, mortar, ceramic materials and glass (Martín-Morales et al. 2013). The presence of fines, such as loose particles, clay clumps and silt, in RCAs provides a higher available surface for aggregates which increases the RCAs’ water/cement ratio, retraction and breakability (Martín-Morales et al. 2011; Tam, Wang & Tam 2008). Due to these impurities, RCAs are always lower in density and higher in porosity and water absorption than natural aggregates (Tam, Tam & Le 2007; Zhao, W, Ren & Rotter 2011). Consequently, contaminated RCAs produce recycled aggregate concrete (RAC) with lower workability and higher water demand in its fresh state (Di Maria et al. 2016). Massive water absorption adversely influences concrete’s fresh and hardened properties (Martín-Morales et al. 2011). Moreover, the presence of excessive chloride content in RCAs leads to the deterioration of RAC due to corrosion of the reinforcement embedded in the concrete (Martín-Morales et al. 2013). The excessive sulphate composition in RCAs reacts with cement components when moisture is

available while making expansive reactions in concrete (Vegas et al. 2015). Furthermore, organic matter in concrete alters the setting and hardening of RAC by decreasing its adhesive properties. Furthermore, even a minimal composition of major damaging impurities like asphalt and aluminium in RCAs diminishes the mechanical, physical and chemical properties of RAC while reducing its durability (Martín-Morales et al. 2013).

In line with many previous studies, it is evident that contamination is the primary cause of quality issues in reprocessed products (Chileshe et al. 2016; Chileshe, Jayasinghe & Rameezdeen 2019; Kartam et al. 2004; Wijewickrama et al. 2021a). Wijewickrama et al. (2021a), through a systematic literature review (SLR), found a few causes which trigger contamination in reprocessed products, as explained in the following subsections.

2.4.1.1 Improper practices in RLSCs of DW

Previous studies found that unplanned pre-dismantling operations, demolition, improper sorting, storing, handling and reprocessing increase the level of contamination (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Xia & Bakker 2014). Although hazardous materials should be removed before dismantling, in most cases, they are commingled with demolition debris (Chileshe, Jayasinghe & Rameezdeen 2019; Townsend et al. 2004). Demolishing a building using explosive or non-explosive mechanical methods is highly disapproved of as it is a destructive and complex dismantling technique encouraging excessive volumes of contaminated waste (Hoang et al. 2022; Saghafi & Teshnizi 2011). Despite these disadvantages, most demolishers follow this technique as it is easy and less time consuming. In most cases, dismantled waste is not sorted on site (Hossain, Wu & Poon 2017; Williams, ID et al. 2014). Consequently, the DW that reaches the off-site sorting facility is mostly commingled and contaminated (Huang, B et al. 2018). Using a single container to collect waste on a demolition site also leads to contamination (Mercante et al. 2012). Sometimes, the DW is stored without separation and loaded directly onto trucks, even after the waste is sorted on site. During transportation, the waste becomes contaminated due to improper stacking inside trucks (Mercante et al. 2012). Furthermore, long distances between the site and the reprocessing facility may also increase the potential for contamination (Tam, Gao & Tam 2006).

2.4.1.2 Lack of policies

A significant challenge in addressing the quality of reprocessed products through contamination is the absence of stringent legislation, regulations, standards and guidelines to regulate the operations in RLSCs of DW (Akinade et al. 2020; Chileshe et al. 2016; Wijewickrama et al. 2022). Consequently, practitioners are not bound to standard procedures for their operations. For instance, Tam (2009) explained that the lack of technical specifications in Australia leads to poor quality reprocessed products. Similarly, del Río Merino, Gracia and Azevedo (2010) reported that the EU countries also lack technical standards regarding reused and recycled building materials. Jayasinghe, Chileshe and Rameezdeen (2019) highlighted that salvageable waste becomes contaminated in SA due to the lack of available standards and specifications specifically related to materials sorting, handling and testing. B Huang et al. (2018) stated that no guidelines have been established for how to classify and determine the degree of contamination of DW in China. In SA, building regulations do not support deconstruction, with this being a significant cause of contamination (Chileshe et al. 2015). The production of reprocessed products has been limited by the above reasons, with myriad issues having been created in relation to quality.

2.4.1.3 Lack of appropriate knowledge and awareness

As stated in the literature, workers in RLSCs of DW lack the skills and knowledge needed for RLSC operations (Chileshe et al. 2015; Chileshe et al. 2016; Nikmehr et al. 2017). For instance, Nikmehr et al. (2017) highlighted that, in most cases, workers engaged in dismantling lack the skills and experience necessary for deconstruction. Supporting this view, Chileshe et al. (2016) found that most dismantling workers in SA do not know the positive advantages of deconstruction when compared to demolition. Not only demolition workers but all practitioners and workers engaged in other RLSC operations lack relevant skills and knowledge (Tam 2009). Additionally, B Huang et al. (2018) revealed that the informal sector in the industry collects DW but most salvageable waste deteriorates in quality as this sector lacks professional guidance and practice. For these reasons, large volumes of commingled waste are produced which are difficult to reprocess. Even if this contaminated waste is introduced to reprocessing, the final products would have quality issues.

2.4.1.4 Lack of advanced technologies

B Huang et al. (2018) highlighted that most quality issues occur due to the unavailability of technological infrastructure needed for RL operations. If reuse and recycling technologies are not well established, this process will ultimately lead to inferior quality products. For instance, Martín-Morales et al. (2013) clarified that reprocessed products might produce chloride and sulphate compounds due to improper off-site mechanical sorting and testing facilities, with chloride and sulphate compounds produced which lead to corrosion and deterioration of hardened concrete. Furthermore, Tam (2009) stated that the paucity of information technology (IT) applications also indirectly leads to quality issues in reprocessed products. Therefore, considering all the above points, the lack of advanced technologies evidently augments contamination to produce inferior-quality reprocessed products.

2.4.1.5 Lack of information flow

Many previous studies highlighted that RLSCs of DW do not receive the benefits from having a well-organised information flow (Cheng & Ma 2013; Chileshe, Jayasinghe & Rameezdeen 2019; Debacker et al. 2017). Consequently, this information deficiency primarily leads to fragmentation and uncertainties in RLSCs of DW (Rahimi & Ghezavati 2018). Even though the information is available, manual handling of information within the process has eventually led to the creation of quality issues in reprocessed products (Cheng & Ma 2013; Chileshe, Jayasinghe & Rameezdeen 2019). Therefore, the lack of proper information flow in RLSCs is found to be a cause of quality issues in reprocessed products (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Xia & Bakker 2014).

As previously mentioned, Wijewickrama et al. (2021a), in their study's SLR, identified five causes that trigger contamination leading to inferior-quality reprocessed products: (i) improper practices in RLSCs of DW; (ii) lack of policies; (iii) lack of appropriate knowledge and awareness; (iv) lack of advanced technologies; and (v) lack of information flow. In the study's important finding, Wijewickrama et al. (2021a) found that the cause, that is, lack of information flow in RLSCs of DW, is triggered by the remaining four causes, leading to contamination, as shown in Figure 2.2. Chileshe, Jayasinghe and Rameezdeen (2019) also revealed a similar point in their study. For instance, when practices, policies, knowledge, awareness and advanced technologies are

insufficient, the information needed to produce quality products would not flow within the supply chain, ultimately increasing contamination and, consequently, quality issues in reprocessed products.

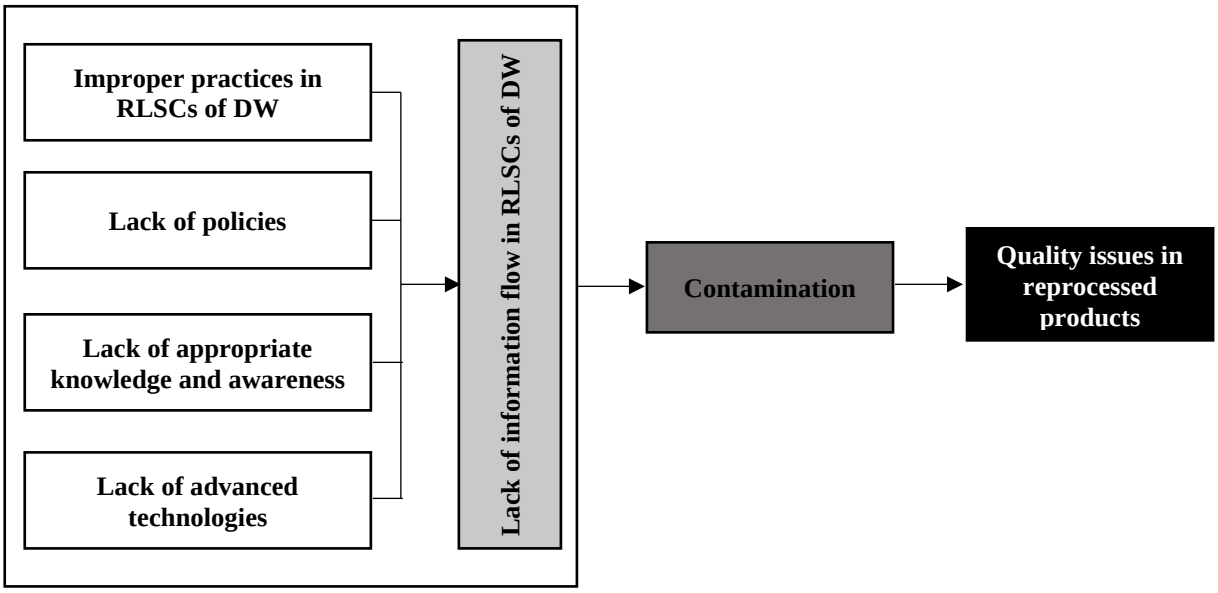


Figure 2.2. Causes of quality issues in reprocessed products

(Source: Adapted from Wijewickrama et al. 2021a)

2.4.2 Quality assurance (QA) in RLSCs

According to Sheikh et al. (2019), final product quality is reliant on how well quality is assured within the production process. Therefore, irrespective of the industry, QA plays an important role in an RLSC, ensuring its process quality to produce a quality output (Nikolaidis 2012; Wijewickrama et al. 2021a). This subsection, firstly, provides a theoretical introduction to QA and, secondly, explains the need for an information-centric quality assurance system (QAS) for RLSCs of DW.

2.4.2.1 Theoretical perspectives of QA

Quality is a multi-faceted notion for which many authors have given multiple definitions. According to the International Organization for Standardization (ISO) (1994), quality is the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs. In early studies, Crosby (1979) and Gilmore (1974) defined quality as conformity to requirements and specifications. For Deming (1986), quality is producing a product or service to satisfy customers. Juran (1988) provided a two-dimensional definition of quality: (i) quality contains product features which meet the needs of customers and thereby provides product satisfaction; and (ii) quality is

associated with customers' requirements, and fitness suggests conformance to measurable product characteristics (p. 22). With these definitions, it is understandable that a complicated and multi-faceted concept like 'quality' cannot be, and possibly should not be, explained by a single definition. However, most of these definitions consensually emphasise that customer requirements significantly determine quality. Accordingly, a well-designed product without defects may not be considered a quality product unless it satisfies the customer's requirements.

An established difference exists between product quality and process quality. Product quality is the quality of characteristics directly related to the physical product (Lyberg & Stukel 2010; Sheikh et al. 2019). On the other hand, process quality means the quality of the process that leads to the product being acceptable. Product quality depends on the quality of the manufacturing process, which includes a series of processing and assembling phases (Lundgren, Hedlind & Kjellberg 2015; Lyberg & Stukel 2010; Pang et al. 2019; Sheikh et al. 2019). In a manufacturing supply chain, every phase and operation in the production process should be designed in the best possible way to produce products of acceptable quality (Lundgren, Hedlind & Kjellberg 2015; Pang et al. 2019). These authors further highlighted that the quality of output of a phase depends enormously on the quality of input for that phase from the preceding phases in a supply chain. Therefore, if quality is assured within all the phases in a supply chain, the entire production process will produce quality output.

Quality management (QM) is a management philosophy (Delis et al. 2017; Tang et al. 2005) that ensures the products and services are acceptable for their intended purpose and that they meet the predetermined requirements (Nikolaidis 2012). Foster (2012) conceptualised QM as an umbrella system constituting two spheres of quality aspects: QA and QC. However, in both practice and research, the terminologies of QC and QA are misleading and, in most circumstances, they have been used in tandem or interchangeably (Han et al. 2012; Patel 2019). As stated by Delis et al. (2017) and Keist (2015), QA is not QC, but QC is one aspect of QA. Quality control (QC) is quality assessment of the deliverable (product or service) which provides confidence that it satisfies the relevant quality standards. On the other hand, QA is all the planned and systematic activities in the process which are implemented with the quality system to provide confidence that the final product will satisfy the relevant quality standards

(Barton & Branstetter 2007; Bushery, Reichert & Blass 2003; McLaughlin et al. 2021). Table 2.3 outlines the differences between QA and QC.

Table 2.3. Differences between quality assurance (QA) and quality control (QC)

	QA	QC
Focus	Focuses on improving the production process used to produce the deliverable.	Focuses on improving the final product by recognising its issues and defects.
Orientation	A process-centred orientation	A product-centred orientation
Approach	Proactive approach	Reactive approach
Verification vs. validation	Verifies whether the right thing is done in the right manner	Validates the compliance of deliverables against the quality requirements
Responsible actors	All the people involved in the production process	QC team of the organisation

(Source: Da Cruz, Cenci & Maia 2006; Gotzamani & Tsiotras 2001; Kadolph 2007; Keist 2015; Nikolaidis 2012; Patel 2019).

The most effective way to improve quality in a production process is to prevent failures before they occur by assuring quality within the process rather than controlling it at the end (Chung 2002; Goldstone 1998; Keist 2015; Nikolaidis 2012). In this vein, Keist (2015) emphasised that it is expensive if organisations do not undertake QA but focus on quality only in terms of QC at the end of the manufacturing process. Schötz et al. (2017) explained that QC is done between two successive production phases to detect defective units before transferring them to the downstream stages. Thus, the non-conformity and failure costs are reduced in an organisation. However, the authors indicated that these QC steps result in extra usage of company resources, such as people, equipment and technology which, in turn, cause extremely high costs. On this note, QA can reduce failure costs during production and expenses incurred due to frequent application of QC measures. Therefore, to achieve an ideal level of synchronisation between high quality and low cost, Schötz et al. (2017) suggested that an effective QAS be implemented within a production process rather than executing QC between production phases.

The QAS of an organisation constitutes the implementation cycle, documentation systems, technologies and human resources needed for QA (Fox 2013; Mulyasa, Sauri

& Aryani 2019). As highlighted by Fox (2013), in a QAS, all the resources used to produce the final product should be adequately controlled throughout the manufacturing process. In fact, it is important that each necessary element in a task be controlled to ensure quality. The author further revealed that each task forms four aspects: process, people, policy and technology, as depicted in Figure 2.3.

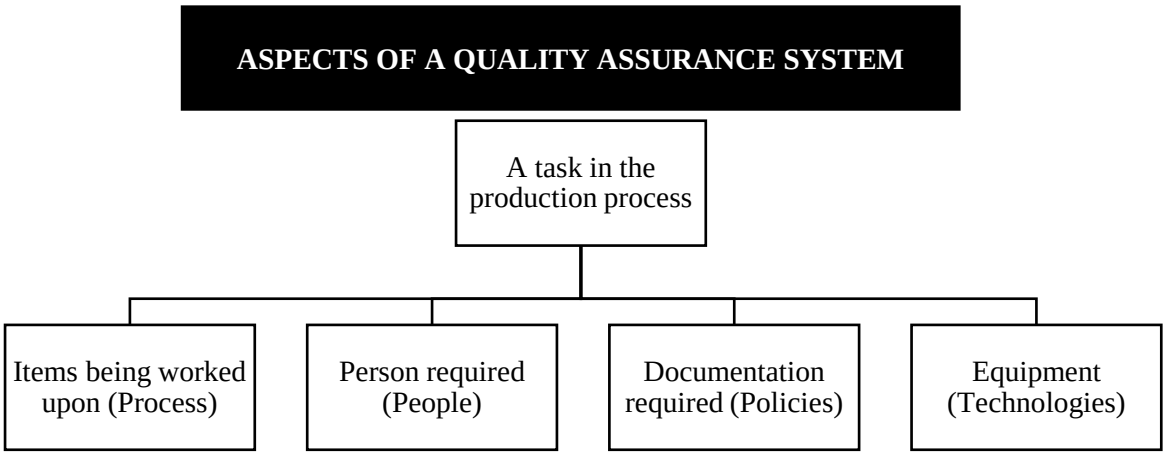


Figure 2.3. Aspects of a quality assurance system (QAS)
(Source: Adapted from Fox 2013)

The development and implementation of a QAS support the organisation to organise and coordinate the internal phases by documenting its operations, clarifying the encountered ambiguities and clearly defining the duties and responsibilities of the people and departments involved in operations (Gotzamani & Tsiotras 2001; Schötz et al. 2017). A well-established QAS is considered an organisation's marketing tool, especially when authorisation is given by third-party certification (Chung 2002). A QAS supports the development of customer and supplier relationships, eventually increasing sales and profits (Karipidis et al. 2009). Based on the above discussion, it is understandable that implementing a QAS provides a good opportunity for organisations in RLSCs to respond proactively to the quality issues of reprocessed products. The next subsection discusses how the QAS should be developed in RLSCs of DW to avoid these quality issues.

2.4.2.2 Quality assurance system (QAS) in RLSCs of DW

To improve the quality of reprocessed products, the building dismantling and on-site processing phase and the off-site waste processing phase in RLSCs of DW should be

quality assured (Chileshe, Jayasinghe & Rameezdeen 2019; Dahlbo et al. 2015; Wijewickrama et al. 2021a). As stated in Subsection 2.4.2.1, process, people, policy, and technology are the aspects of a QAS. Similarly, the QAS in an RLSC of DW is supported by its process, people, policy and technology. The following subsections describe how each aspect is important for QA in RLSCs of DW, as per the findings of the SLR by Wijewickrama et al. (2021a).

2.4.2.2.1 Process for QA in RLSCs of DW

The RLSC is an interrelated process in which the operational effectiveness of a phase significantly depends on the effectiveness of the previous phase (Chileshe, Jayasinghe & Rameezdeen 2019; Sroufe 2013). Thus, if the quality is assured in the initial phases, it will be easy to assure the quality of subsequent phases while achieving a high-quality output at the end (Chileshe, Jayasinghe & Rameezdeen 2019). Consequently, QA in RLSCs of DW should be initiated from the building dismantling and on-site processing phase as it is the supply chain's starting point.

Deconstruction is a favoured technique for dismantling buildings that maximises the recovery rate of salvageable waste while diverting waste from landfill (Akinade et al. 2020; Debacker et al. 2017). Therefore, the decision to deconstruct instead of carrying out mechanical demolition is a practice in the process of QA in RLSCs of DW (Chileshe et al. 2018). However, the hybrid method, a combination of deconstruction and demolition, has attracted the attention of practitioners as an ideal dismantling technique to maintain the quality of salvageable materials while responding to the cost and time pressures of re-development (Vegas et al. 2015). Extreme efforts to provide highly sorted materials to a reprocessing facility are also crucial in determining the quality of reprocessed products (Chileshe, Jayasinghe & Rameezdeen 2019; Kartam et al. 2004). Consequently, in countries like Hong Kong, on-site sorting is an obligatory requirement (Tam, Wang & Tam 2008) as it helps to segregate hazardous and contaminated waste before it contaminates other waste (Williams, ID et al. 2014). On a demolition site, several moveable containers should be positioned at different on-site locations from the beginning of dismantling to support on-site sorting (Tischer, Besiou & Graubner 2013). The sorted waste on different building floors should be transported through vertical ducts to the ground floor as manual transportation could increase the contamination of salvageable materials (da Paz et al. 2014). Moreover, extracted salvageable materials should be stored appropriately to avoid contamination and

exposure to unfavourable weather conditions (Jiménez-Rivero & García-Navarro 2016). The proper transportation and handling activities of salvageable waste between collection sites and reprocessing facilities are also crucial for QA (Trochu, Chaabane & Ouhimmou 2018). Furthermore, these authors stated that selecting a reprocessing facility closer to the demolition site is crucial to minimise contamination during transportation.

The process for QA during the off-site waste processing phase should start from the point at which the MRF receives salvageable waste. The random collection and handling by unprofessional waste pickers accelerate the contamination of EoL waste (Huang, B et al. 2018). Therefore, MRF operators should check the quality of salvageable waste provided by different suppliers. A detailed preliminary inspection is important to determine whether DW is mostly made up of inert materials or mixed waste (Mercante et al. 2012). The mixed waste is sorted with support from a backhoe to remove substantial-sized materials which would damage the sorting circuit and lessen the quality of reprocessed products (Zhao, W, Ren & Rotter 2011). Throughout this phase, chemical tests are carried out to ensure the salvageable waste is not mixed with hazardous materials like asbestos (Chileshe et al. 2016). After several pre-treatments, the salvageable materials are subjected to bar screening, disk screening, magnetic separation, air classification and final manual separation (Townsend et al. 2004). In some circumstances, blending natural materials with reprocessed materials is considered a QA practice during the off-site waste processing phase (Lotfi et al. 2014). Admixtures can also be used to enhance the quality of the reprocessed products (Wagih et al. 2013). For instance, silica fume can be used as a mineral admixture to improve adhesion between new and old mortar attached to RCAs. The reprocessed products should be re-checked, tested and graded based on their quality before being dispatched to the secondary market (Chileshe, Jayasinghe & Rameezdeen 2019; Sangiorgi, Lantieri & Dondi 2015). Furthermore, they should be distributed by offering a ‘label’ or ‘grading stamp’ as an assurance for potential customers (Chileshe et al. 2016). Thus, customers will gain a detailed understanding of the quality of reprocessed products and of any potential hazards or risks involved with these products. This crucial QA practice undeniably promotes reprocessed products in the market.

2.4.2.2.2 People for QA in RLSCs of DW

ID Williams et al. (2014) highlighted that the workforce engaged in on-site sorting should be skilful and knowledgeable on the associated regulations and procedures. Training is essential for workers who engage in the entire RLSC so they can undertake QA practices effectively and efficiently (Calvo, Varela-Candamio & Novo-Corti 2014). The organisation's top management should make workers aware of the benefits, challenges and procedures of deconstruction and other related on-site QA practices (Debacker et al. 2017). All demolition workers who work on demolition sites should have a licence from the corresponding authorities (Nikmehr et al. 2017). A qualified professional should be appointed at the site to periodically supervise dismantling and on-site sorting (Jiménez-Rivero & García-Navarro 2016).

Debacker et al. (2017) highlighted that active collaboration and communication between parties within the entire life cycle of a building are vital for QA in RLSCs of DW. Tam (2009) suggested including recyclers as one of the project parties in a construction project to improve communication and collaboration between the construction and dismantling phases. These recyclers could make more technical decisions through their practical experience in waste management operations on site. Alternatively, Tischer, Besiou and Graubner (2013) suggested using a logistics service provider who would support the practices during the construction and dismantling phases. The logistics service provider would focus on the key logistics processes directly on site and produce better collaboration between project participants to assure the quality of post-EoL operations. Akinade et al. (2020) also recommended involving demolition managers and specialists in the early design stage of a building. These authors specified that these demolition specialists could help by suggesting building methodologies that would facilitate deconstruction during the EoL phase of a building.

2.4.2.2.3 Policies for QA in RLSCs of DW

Blaisi (2019) highlighted that legislation is needed to mandate the best practices for managing DW efficiently and effectively. Aminu and Lee (2018) pointed out that, in the UK, the Site Waste Management Plan Regulations of 2008 mandate the development of a comprehensive waste management plan for buildings valued at over £300,000. Even though regulations in some countries encourage QA practices, the execution of QA practices in RLSCs of DW faces some issues due to regulations. For instance, Chileshe et al. (2016) indicated that on-site sorting is not viable in SA due to stringent safety

regulations and environmental codes. In addition to mandating best practices, Blaisi (2019) specified that regulations are also needed to promote the utilisation of new or existing technologies to assure quality within the process of RLSCs of DW.

The operations within an entire RLSC of DW rely on standards, procedures and guidelines. Poon, Yu and Ng (2001) specified that proper guidelines are necessary to implement the correct handling and storage procedures of salvageable materials on site. Furthermore, Jiménez-Rivero and García-Navarro (2016) highlighted that MRFs need waste acceptance criteria guidelines to decide whether to accept or reject salvageable waste loads coming into their facilities. The study by Martín-Morales et al. (2011) highlighted that the entire off-site reprocessing phase complied with standards and guidelines to assure the quality of reprocessed products. Additionally, Adams et al. (2017) confirmed that insurance and warranty schemes are required to assure the quality of reprocessed products when they are introduced to the secondary market. Therefore, all the above assertions establish the view that policies are required to enforce QA in RLSCs of DW.

2.4.2.2.4 Technologies for QA in RLSCs of DW

The continuous development of technologies improves the quality of reprocessed products (Huang, B et al. 2018). According to Rose and Stegemann (2018), buildings are considered ‘material banks (deposits)’ which actively manage accounts of materials over the building life cycle through technologies such as the Internet of Things (IoT) and Building Information Modelling (BIM). Debacker et al. (2017) introduced two innovative solutions, namely, ‘materials passport’ and ‘reversible building design’, to support RL operations. The materials passport is a digital repository of data that defines the characteristics and provides value for the present use, recovery and reuse of materials in a building. These authors emphasised that storing and managing digital and centralised building information related to current, past and potential future situations are vital for the success of post-EoL operations.

Lotfi et al. (2014) introduced a sensor-based online QA technology to upgrade materials extracted after demolition. Kleemann et al. (2017) proposed a remote sensing approach for monitoring dismantling sites. The authors explained that this innovative approach helps to estimate the quantity of DW generated from a building that is to be dismantled. Sobotka et al. (2017) highlighted that more refined sorting methods, such as

aerodynamic screening, hydrocyclone classification and optical sorting systems, are needed to ensure the quality of reprocessed products. Vegas et al. (2015) introduced a programmed near infra-red (NIR) technology to recognise and selectively remove pre-known impurities from RCAs. A hyperspectral imaging-based sensing device is able to detect and characterise different salvageable materials in DW (Serranti, Palmieri & Bonifazi 2015). Therefore, this technological device ensures the quality of reprocessed products produced from DW.

Ding, Xiao and Tam (2016) revealed a few advanced technologies used to remove hardened mortar from RCAs. For instance, aggregate shaping equipment is used to refine the shape of RCAs by removing most of the attached old mortar. This equipment generates high-speed rubbing on the surface while making a smooth finish, as in natural aggregates (Ding, Xiao & Tam 2016). Moreover, Di Maria et al. (2016) proposed a novel technology to estimate the particle size distribution of aggregates based on image analysis. Klang, Vikman and Brattebø (2003) highlighted that an electrically powered hydraulic machine with steel edges could be used to remove old mortar from bricks. Tam (2009) described some new technologies used in Japan to improve the quality of RCAs, such as heating and grinding methods, screw grinding, mechanical grinding and gravity concentration methods. All the above technologies aim to upgrade the physical, chemical, mechanical and geometrical properties of RCAs.

2.4.2.3 Information-centric QAS in RLSCs of DW

As described in Subsection 2.4.2.2, QA is not a solitary effort in the RLSCs of DW. As shown in Figure 2.4, QA efforts should be undertaken as a system of four aspects: process, people, policy and technology. It is worth mentioning that QA does not become workable if any of these aspects do not perform effectively and efficiently or do not synchronise with other aspects while performing. Therefore, Wijewickrama et al. (2021a) indicated that an integrated system of process, people, policy and technology is imperative for producing quality output from RLSCs of DW. The process includes practices and approaches required specifically for QA in RLSCs of DW. Experienced and knowledgeable people should undertake the QA practices and approaches by complying with the available policies while using new or available technologies. In addition, these people should always be collaborative and good at communicating. The QAS should be equipped with innovative equipment and plants while receiving support from information and communication platforms (Chileshe, Jayasinghe & Rameezdeen

2019; Wijewickrama et al. 2021a). When high-tech machines, equipment and IT-enabled platforms are incorporated into the system, the people and process aspects become efficient and effective (Bartel, Ichniowski & Shaw 2007). From the policy perspective, the QAS should be well framed within the requirements of current legislation, regulations, standards and guidelines (Brandão et al. 2021b; Fox 2013). Accordingly, the policies should be stringent to lead the process, people and technologies needed for QA. With this in place, it is comprehensible that all four aspects should be integrated for QA in RLSCs of DW. Interestingly, Wijewickrama et al. (2021a) asserted that information is the source that integrates these four aspects. Thus, an information-centric environment should be available for QA in RLSCs of DW.

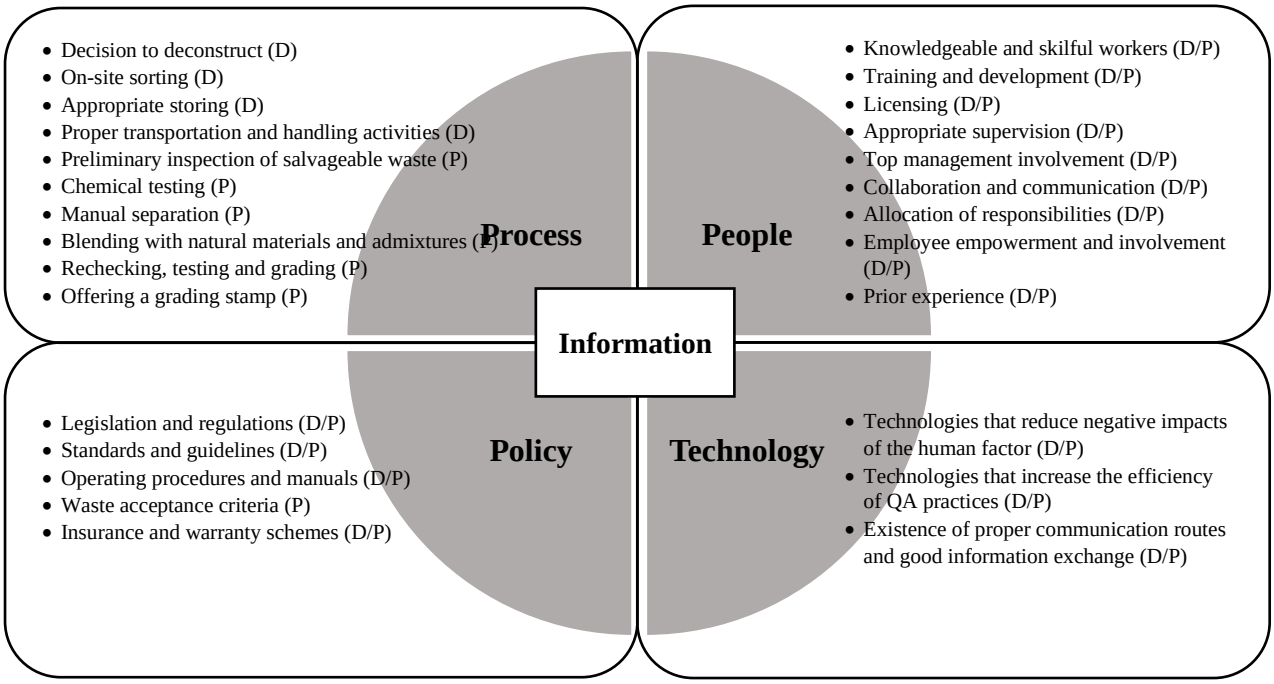


Figure 2.4. Information-centric quality assurance (QA) in RLSCs of DW

2.4.3 'Information deficiency' as a significant barrier to RLSCs of DW

As shown in Table 2.2, the body of literature has recurrently outlined that information deficiency, an operational barrier, is a serious issue in RLSCs of DW. Z Wu et al. (2022) indicated that the useful information in an RLSC is confined within the supply chain, as some is trapped within the business entities, while other information cannot even be found throughout the supply chain. Thus, all the phases are deficient in useful information, making the supply chain integration more complicated in RLSCs of DW

(Rameezdeen et al. 2015; Tennakoon, Rameezdeen & Chileshe 2022). Consequently, the operations in RLSCs, especially QM efforts, are being adversely affected due to the lack of useful information (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b; Xia & Bakker 2014). The term 'useful information' means an organised body of data or knowledge used to make an array of decisions and guided actions (Lotfi et al. 2013). The following subsections outline the useful information needs of RLSCs of DW and explain why information is not shared in the supply chain.

2.4.3.1 Need for useful information in RLSCs of DW

As explained in Section 2.3, an RLSC of DW encompasses a chain of operational phases that introduce salvageable materials from DW to a new construction project. Information sharing plays an imperative role in RLSCs of DW as it strengthens the coordination and collaboration between internal stakeholders to deliver products in a timely manner to match the current industry demand (Rameezdeen et al. 2015; Wijewickrama et al. 2021b; Wu, Z et al. 2022). In supply chain management, information sharing refers to the exchange of useful information between stakeholders or organisations (Safdar et al. 2020). Although forward logistics consider producing the right product at the right time, RL's primary concern is making the right decision in the right place (Zheng, Zheng & Liu 2005). These right decisions are mostly based on the availability of useful information. Consequently, as indicated in its definition, the RLSC is not only concerned with the physical movement of salvageable waste and finance but also with the associated flow of information (Chileshe et al. 2015; Tennakoon, Rameezdeen & Chileshe 2022). Notably, the information flow in an RLSC is also essential to manage the other two flows of materials and finance (Wijewickrama et al. 2021b; Zheng, Y, Zheng & Liu 2005). Therefore, adopting RLSCs within an information-centric environment is fundamental to enhancing the operational performance of resource recovery while diverting the maximum amount of DW from landfill at the EoL of a building.

Table 2.4 outlines the information needs of each phase in an RLSC of DW. The RLSC starts with the need for useful information (Wijewickrama et al. 2021b). Furthermore, these authors elaborated that after the decision to dismantle is made, the first step for the demolisher is to gather information about the building, such as the type, age, size, location and history of the building and a brief estimation of the waste to be generated.

Generally, the demolisher tries to collect most of the above information via site visits and detailed assessments of building-related documents such as drawings and asbestos registers. For instance, a detailed reference to construction drawings is required to understand structural capacities and stability and to determine the extent to which the elements and materials are to be stripped before the mechanical demolition of the building (Chileshe, Jayasinghe & Rameezdeen 2019). In the same way, pursuing the asbestos register of a building helps the demolisher to understand the presence of any hazardous materials before commencing the dismantling (Chileshe, Jayasinghe & Rameezdeen 2019) and the procedures to manage them (Saghafi & Teshnizi 2011). Furthermore, Ge et al. (2017) highlighted that the demolisher needs information on the site conditions, safety requirements, cost and time allowed for demolition and the need for site clearance for a new structure before initiating the dismantling. Gathering this information before dismantling helps the demolisher to decide on the appropriate demolition and subsequent reprocessing methods.

Table 2.4. Information needs of each phase in an RLSC of DW

Phase in the RLSC	Information needs
Building dismantling and on-site processing	• Basic information and materials composition of the building • Site conditions • Information on the presence and procedures to handle hazardous materials • Potential use of materials to be produced • Information on staffing, machine deployment and waste discharging • Location and details of service deviations and terminations • Government planning requirements • Information on on-site waste treatment • Cost and time allowed for operations • Information on safety requirements • QA/QC procedure • Information on transportation
Off-site waste processing	• Quantity, quality and location of the salvageable waste • Requirements to accept salvaged waste for reprocessing • Information on ways of classifying the waste • Information on the secondary market

(Source: Adopted from Wijewickrama et al. 2021b)

In the off-site waste processing phase, the waste processor needs information about the MRF's requirements for accepting the salvageable waste (Jiménez-Rivero & García-Navarro 2016). If the waste loads do not comply with these requirements, the waste processor will not accept them for further processing. It is crucial to obtain information on the quantities of different classifications of DW before introducing it to the

reprocessing facility (Munaro et al. 2019). As DW can be generated from different demolition sites, obtaining information on when, where and by which activities the waste is produced is also essential (Munaro et al. 2019). During reprocessing, the waste processor must comply with information available on product standards and guidelines to check whether the reprocessed products meet the required specifications (Wijewickrama et al. 2022). Moreover, information on the secondary market for reprocessed products, prevailing prices and price volatility is also needed for this phase (Huang, WL et al. 2002; Ratnasabapathy, Alashwal & Perera 2021). Based on this information, the waste processor can decide on the reprocessing method, production amount and product quality requirements.

2.4.3.2 Why is information not shared?

No systematic method exists for sharing information in RLSCs in the construction industry (Chileshe, Jayasinghe & Rameezdeen 2019; Rameezdeen et al. 2015). The value chain of a construction facility mainly consists of four phases: conceptualisation and design; construction; usage and operation; and repurposing and deconstruction/ demolition (Debacker et al. 2017). Various stakeholders are engaged in these phases, but none will be involved throughout all value chain phases. Wijewickrama, Rameezdeen and Chileshe (2021) found a relatively established relationship between actors engaged in the design and construction phases, but this connection rarely moves beyond the usage and operation phase. Thus, much valuable information on the design, construction and operation phases is not communicated to actors involved in the repurposing and deconstruction/demolition phase. Therefore, RLSCs of DW are initiated with a substantial information gap which becomes acute when moving along the supply chain phases.

An RLSC of DW is an extremely fragmented, unorganised, cross-functional and multidisciplinary process comprising a sequence of interrelated phases (Chileshe et al. 2015; Chileshe, Rameezdeen & Hosseini 2016). It is a complex supply chain due to the dispersed locations of process facilities and the difficulties in predicting the quantity of waste (Chileshe, Rameezdeen & Hosseini 2016; Trochu, Chaabane & Ouhimmou 2018). It also involves multiple stakeholders with diverse information needs who are required to make decisions collaboratively (Chileshe, Rameezdeen & Hosseini 2016). For these reasons, the internal phases in an RLSC of DW are poorly integrated; thus, useful information acquisition, processing and sharing have become complicated.

In addition to the intrinsic complex nature of the supply chain, previous studies highlighted many barriers which impede information sharing in RLSCs in the construction industry. For instance, Gan and Cheng (2015) revealed that the lack of trust between business entities and senior management involvement hinder information sharing in RLSCs in the construction industry. Plant, Xu and White (2015) found that the lack of IT infrastructure, IT capabilities and qualified staff are a few barriers to information sharing in RLSCs of DW. Additionally, in a recent study, Z Wu et al. (2022) identified lack of certainty in the market environment, lack of trust between stakeholders and lack of government support as the three most significant barriers that impede information sharing in RLSCs of DW. Many reasons are evident for why information sharing is not happening systematically in RLSCs of DW; thus, most of the useful information is unavailable for internal stakeholders to make decisions. On this note, stakeholders in RLSCs should find appropriate ways to process useful information in response to their information deficiencies to achieve operational performance criteria, such as QA, whereas the failure to do so would jeopardise the supply chain's performance. Providing a predominant theoretical lens, organisational information processing theory (OIPT) explains the importance of information processing for an entity's operational performance, as described in detail in the following sections.

2.5 Theoretical Perspectives of Organisational Information Processing Theory (OIPT)

Organisational information processing theory (OIPT) provides an excellent outline for understanding organisational behaviour. The seminal study by March and Simon (1958) launched the initial information processing model of organisations positing that organisations are information processing systems that naturally respond to information deficiencies. Since then, many subsequent studies expanded upon this view from different perspectives (e.g., Cyert & March 1963; Galbraith 1973, 1974, 1977; Williamson 1975). Of these, the most substantial knowledge on the subject stems from Galbraith's (1973, 1974, 1977) works, with the OIPT later developed by this author.

The OIPT introduces organisations, such as demolishers and waste processors, as information processors under uncertain circumstances (Galbraith 1973, 1974; Haußmann et al. 2012; van den Berg, Voordijk & Adriaanse 2020). The original OIPT

explains uncertainty, which leads to IPNs, as the determinant of an organisation's structure (Sen et al. 2022). The word 'uncertainty' is defined as:

> The difference between the amount of information required to perform the task and the amount of information already possessed by the organisation. (Galbraith 1973, p. 5)

In an aspect foundational to this definition, many prior studies later asserted that epistemic uncertainties are caused by a lack of information (Brugnach et al. 2008; Filippi & Vasile 2021; Khanmohammadi 2021; Walker et al. 2003). For instance, Brugnach et al. (2008) explained epistemic uncertainties as:

> … situations where we don't know enough about the system to be managed, or where our knowledge about it is incomplete ... This can be due to a lack of information or data, to the unreliability of the data that [are] available, to lack of theoretical understanding, or to ignorance. (p. 6)

In an organisation, if the tasks are well understood and planned before their execution, fewer epistemic uncertainties will be present (Galbraith 1974). In contrast, if the task is not well understood, it cannot be pre-planned and will demand more information for execution, resulting in changes in resource allocation, schedules and priorities. According to Fox (2013), a task in an organisation can be divided into four aspects (see Figure 2.3): (i) item being worked upon (process); (ii) person required (people); (iii) documentation required (policies); and (iv) equipment (technologies). A task's behaviour cannot be determined as good or bad as it depends on the behaviours of each of these aspects. As outlined in Subsection 2.4.2, organisations in RLSCs of DW have difficulty integrating these aspects, thus, creating epistemic uncertainties which hinder the achievement of organisational performance.

In OIPT, information processing is the key concept, based on which OIPT has developed the primary proposition that:

> The greater the task uncertainty, the greater the amount of information that must be processed among decision-makers during task execution in order to achieve a given level of performance. (Galbraith 1974, p. 28)

Information processing encompasses the gathering, interpreting and synthesising of information for organisational decision making (Li et al. 2021; Tushman & Nadler 1978). The word 'information' refers to 'data which are relevant, accurate, timely and concise' (Tushman & Nadler 1978, p. 614). The strategies which could be executed to handle organisational epistemic uncertainties were later acknowledged as IPMs (Busse,

Meinlschmidt & Foerstl 2017; Foerstl, Meinlschmidt & Busse 2018). According to Galbraith (1973), organisations should undertake appropriate IPMs according to the type of epistemic uncertainties that they encounter. The theory posits that the IPNs should match the IPMs of the organisation to achieve performance in organisational activities, such as QA, whereas mismatches jeopardise organizational performance.

Previous studies postulated that the organisation's external environment is resistant to change, while the internal organisational processes are more adaptable (Sousa & Voss 2008). Consequently, based on OIPT, many IPMs have been put forward which could be undertaken by internal organisations in response to epistemic uncertainties. For instance, the seminal study by Galbraith (1974) first mentioned three types of IPMs that an organisation could undertake in response to task uncertainties: 'rules and programs', 'hierarchical referral' and 'goal setting'. Rules and programs are appropriate as they provide a known response to task uncertainties that can be predicted in advance as they have arisen in the past. When exceptions to these rules and programs increase, epistemic uncertainties that later evolve would be resolved through hierarchical referral (i.e., the infrequent problems referred to the next level in the organisational hierarchy). Instead of specifying everything through rules and procedures, organisations establish targets and goals for employees so they can decide the appropriate behaviours they should undertake during epistemic uncertainties that are not routine or predictable. According to Galbraith (1974), when epistemic uncertainties increase, the organisational hierarchy becomes overwhelmed and is left with two options: either reducing IPNs or increasing the information processing capacities (IPCs) of the organisation. Table 2.5 outlines the IPMs that appear under the above options. Accordingly, to reduce IPNs, the organisation could create slack resources (i.e., increasing the planning targets to encounter few exceptions) and/or self-contained groups (i.e., groups including all resources and capabilities for completeness). From these IPMs, fewer exceptions are expected to occur, and even if they occur, less factors need to be considered. Moreover, to increase IPCs, organisations could invest in information systems and/or create lateral relationships that enable them to process new information for task performance by avoiding related epistemic uncertainties.

Through their study, Daft and Lengel (1986) found, in addition to uncertainties, that equivocality also represents a complementary force in organisations that demand information processing. According to these authors, equivocality means 'ambiguity, the

existence of multiple and conflicting interpretations about an organizational situation' (p. 556) due to many sources of information. As the body of literature recurrently outlined that RLSCs of DW lack the required useful information, the current study was limited to only studying epistemic uncertainties and excluded equivocality. Furthermore, Daft and Lengel (1986) asserted that IPMs responding to epistemic uncertainties could be determined by their capacity to process rich information. These authors defined information richness as 'the ability of information to change understanding within a time interval' (p. 560). On the one hand, IPMs with rich information, such as 'group meetings' and 'creation of integrator roles', were generally face-to-face measures and provided immediate feedback. On the other hand, IPMs, which provided less rich information, such as 'rules and programs' and 'planning and goal setting', were more impersonal, processed fewer cues and restricted feedback. Daft and Lengel (1986) posited, as an interesting finding, that less rich and more impersonal IPMs, that were effective for processing well-understood messages and standard information, were more effective in reducing epistemic uncertainties in an organisation.

Table 2.5. Information processing mechanisms (IPMs) under high uncertainty

	IPMs	Description
Decrease IPNs	Creation of slack resources	By creating slack resources, organisations are increasing their planning targets to reduce exceptions; thus, the need for information processing will become less. As slack resources decrease the interdependence between subunits, fewer factors will be considered during an exception. Therefore, reduced exceptions and interdependencies eventually lead to less IPNs.
	Creation of self-contained tasks	The organisation could reduce IPNs by congregating the resources needed to perform the tasks directly to different subunits. This would reduce the amount of output diversity due to specialisation in one type of output and less division of labour. Therefore, IPNs can be reduced by minimising exceptions from self-contained tasks as they reduce the level of performance, diversity of output and division of labour.
	Control the organisation's environment	The control mechanisms within the organisation's environment could be implemented to reduce uncertainty rather than changing the organisation. The organisation could employ strategic decisions to control the organisational environment to reduce IPNs.
Increase IPMs	Investment in vertical information systems	Utilising computers and various man–machine combinations increases IPCs in organisations when the frequency of re-planning increases with increasing uncertainty. The design variables of these information systems rely on the decision frequency, the degree of formalisation of language and the type of decision mechanism.

	Creation of lateral relationships	When IPNs are overloaded, decision making should be done in the hierarchy where the required information is available. Simply stated, decision making becomes decentralised; thus, the information does not have to be processed at higher levels in the hierarchy to make decisions. Several lateral relationship mechanisms include direct contact, liaison role, task forces, teams, integrating roles and the matrix organisation.

(Source: Galbraith 1973, 1974; Haußmann et al. 2012).

The OIPT, originating as it does from the seminal work by Galbraith (1973, 1974), is a relatively simple but sophisticated formulation that has served as the theoretical foundation for many conceptual and empirical studies in different organisational contexts. However, from the construction industry perspective, only a few scholars have attempted to apply OIPT. These include studies that quantify epistemic uncertainties in construction projects (Chang & Tien 2006); identify and differentiate construction clients' ability to manage epistemic uncertainties (Levander et al. 2011); and provide insights on barriers to overcoming inertia in client decision making (Engström & Hedgren 2012). Despite the applications of OIPT in FSCs, no study has attempted to adopt it in RLSCs in the construction industry until the recent study by van den Berg, Voordijk and Adriaanse (2020). This study focused on EoL building coordination from the perspective of demolition organisations. On this note, no previous study has viewed the holistic representation of information processing in RLSCs of DW from an OIPT perspective, which is the purpose of the current study.

2.5.1 OIPT in the supply chain context

The field of supply chain management has demonstrated growing interest in using theories to explore, explain and develop relationships between important concepts (Ketchen & Hult, 2011; Swanson et al. 2017). These authors further revealed that the theories originating from organisational sciences to identify how to improve organisational performance could be successfully applied in the supply chain management context. Specifically with an intra-organisational focus, OIPT also evolved from the organisational sciences, in response to organisational design problems arising from uncertainty (Galbraith 1973). However, it was later applied at an inter-organisational level to evaluate information processing, especially in dyadic supply chains.

When applying OIPT, solely rooted in the organisational context, to the supply chain context, it is necessary to distinguish the theoretical analogy between a supply chain and

an organisation. An organisation consists of ‘a set of interdependent elements that comprise a whole, which each contributes something to and receives something from, in return’ (Flynn, Koufteros & Lu 2016, p. 4). These elements in the organisation act as functional departments devoted to specialised tasks. If an organisation has a dysfunctional element, that element will either regulate its performance to provide a positive contribution or disengage from the organisation (Flynn, Koufteros & Lu 2016). Moreover, organisations are homeostatic in nature amid the turbulence of their external environment (Burnard & Bhamra 2011; Thompson 1967). On the other hand, a supply chain is defined as a network that exists within an organisation or between several organisations (Min, Zacharia & Smith 2019). It includes a series of processes to procure raw materials, convert them to final products and distribute them to markets. The word ‘organisation’ can be applied to a supply chain as its members contribute goods and services and receive revenue in return (Flynn, Koufteros & Lu 2016). A member in the supply chain is equivalent to a functional department in an organisation (Hult, Ketchen & Slater 2004; Shabbir et al. 2019) and is focused on a single task within the supply chain. These supply chain members are regulated via an evolutionary process and governed by homeostasis (Flynn, Koufteros & Lu 2016). These authors further highlighted that, as in an organisation, if a dysfunctional member is present in the supply chain, this member either adjusts or disengages from the entire supply chain.

However, key differences between an organisation and a supply chain need to be pointed out with a high level of scrutiny. Liu et al. (2021) emphasised that a supply chain has the potential to move mindsets from intra-organisational-focused operations to more diverse and collaborative inter-organisational processes. For instance, in the intra-organisational context, a task consists of several sub-tasks. These individual sub-tasks should be coordinated to accomplish the global task, eventually leading to organisational performance (Galbraith 1973, 1974). On the other hand, in the supply chain (i.e., inter-organisational context), these sub-tasks must be coordinated across separate firms to achieve the supply chain’s ultimate goal (Forster 2000). Due to their high levels of interdependence and differentiation, supply chain members encounter more competing pressures than elements in an organisation. In line with this statement, Han, Caldwell and Ghadge (2020) revealed that a high reciprocal interdependence relationship exists in a supply chain where outputs of one member become inputs for others. While products, information and finance flow internally inside an organisation,

the same flows move across a network of organisations in some supply chains (Wang, H, Mastragostino & Swartz 2016). Furthermore, supply chain members are independent firms that perform in their own interests and are dissimilar in structure, inner culture, resources and commitment to the supply chain's performance (Ireland & Webb 2007; Xiao et al. 2019). Consequently, organisations in a supply chain have varying needs and capacities depending on their role in the supply chain. In most circumstances, supply chain members are simultaneously attached to more than one supply chain (Dong & Kouvelis 2020; Hult, Ketchen & Slater 2004). Therefore, when organisations are supported by a robust inherent culture and common affiliation, the primary loyalty of supply chain members is to their firms or adjacent supply chain members.

Despite the theoretical view of the supply chain as an organisation, some intrinsic characteristics of the supply chain differentiate it from an individual organisation. In this regard, it is doubtful whether OIPT, rooted as it is in the intra-organisational context, is without challenges when applied in the inter-organisational context. A supply chain consists of a network of individual organisations with different interests and performing various activities to achieve mutually defined goals (Raweewan & Ferrell 2018; Shukla 2016; Sluis & De Giovanni 2016). These organisations have different relationships, risks and uncertainties which would not be encountered in an independent organisation. Therefore, a theory like OIPT can be rationally applied to a supply chain context while considering each supply chain member as an individual organisation (Ketchen & Hult 2011; Swanson et al. 2017). In line with this, Haußmann et al. (2012) specifically mentioned in their review that, despite OIPT focusing on the intra-organisational level as a response to organisational design problems, it can also be applied to an inter-organisational orientation. In compliance with this view, shreds of evidence show that previous studies have successfully bridged this intra-organisational theory (i.e., OIPT) across to supply chain contexts where several organisations are linked through materials, financial and information flows. These studies, summarised and presented in Table 2.6, have been conducted based on various industries.

Table 2.6. Previous studies which adopted OIPT in the supply chain context

References	Industry/sectors	Category (FSC/ RLSC)	Source country of data collection	Methodology	Research concepts in supply chain management to which OIPT has been applied							
					Coordination	Sustainability	Uncertainty/ Equivocality	Integration	Disruption risks	Practices	Knowledge development	Environmental complexity
van den Berg, Voordijk & Adriaanse (2020)	Construction industry	RLSC	Netherlands	Multiple case studies	√							
Dahlmann & Roehrich (2019)	Manufacturing industry	FSC	Global	Secondary data sources		√						
Yu, W et al. (2019)	Manufacturing industry	FSC	China	Questionnaire survey				√				
Bartnik & Park (2018)	Manufacturing industry	FSC	Japan, Germany, China	Multiple case studies				√				
Foerstl, Meinlschmidt & Busse (2018)	Manufacturing industry (chemical, pharmaceutical, furniture, apparel industries)	FSC	Global	Multiple case studies		√						
Busse, Meinlschmidt & Foerstl (2017)	Manufacturing industry (chemical, pharmaceutical, furniture, apparel industries)	FSC	Global	Multiple case studies		√						
Kreye (2017)	Electronics sector	FSC	UK	Multiple case studies			√					
Wiengarten et al. (2017)	Manufacturing industry	FSC	USA, Australia, Vietnam, Poland, Croatia, Ireland	Questionnaire survey		√						
Flynn, Koufteros & Lu (2016)	Manufacturing industry (electronics, machinery and	FSC	Finland, Sweden, Germany, Italy, Austria, Japan,	Questionnaire survey				√				

References	Industry/sectors	Category (FSC/ RLSC)	Source country of data collection	Methodology	Research concepts in supply chain management to which OIPT has been applied							
					Coordination	Sustainability	Uncertainty/ Equivocality	Integration	Disruption risks	Practices	Knowledge development	Environmental complexity
	transportation components)		South Korea, USA, Brazil, Spain, China									
Srinivasan & Swink (2015)	Manufacturing industry, retail and distribution sectors	FSC	Global	Questionnaire survey				√				
Swink & Schoenherr (2015)	Manufacturing industry, retail and distribution sectors	FSC	Global	Questionnaire survey and secondary data sources				√				
Feger (2014)	Manufacturing industry	FSC	USA	Questionnaire survey				√				
Williams, BD et al. (2013)	Manufacturing industry, retail and distribution sectors	FSC	Global	Questionnaire survey				√				
Schoenherr & Swink (2012)	Manufacturing industry, retail and distribution sectors	FSC	Global	Questionnaire survey				√				
Bode et al. (2011)	Manufacturing industry	FSC	Germany, Austria, Switzerland	Questionnaire survey					√			
Cousins et al. (2011)	Manufacturing industry	FSC	UK	Questionnaire survey							√	
Levander et al. (2011)	Construction industry	FSC	Sweden	Multiple case study and questionnaire survey			√					

References	Industry/sectors	Category (FSC/ RLSC)	Source country of data collection	Methodology	Research concepts in supply chain management to which OIPT has been applied							
					Coordination	Sustainability	Uncertainty/ Equivocality	Integration	Disruption risks	Practices	Knowledge development	Environmental complexity
Narayanan et al. (2011)	Business process outsourcing (BPO) industry	FSC	India	Questionnaire survey				√				
Wong, Boon-itt & Wong (2011)	Automotive industry	FSC	Thailand	Questionnaire survey				√				
Gattiker (2007)	Manufacturing industry	FSC	USA	Questionnaire survey				√				
Hult, Ketchen & Arrfelt (2007)	Manufacturing industry	FSC	USA	Questionnaire survey							√	
Meijboom, Voordijk & Akkermans (2007)	Construction industry, semiconductor industry, fashion industry, aviation industry	FSC	Netherlands	Multiple case studies	√							
Swink, Narasimhan & Wang (2007)	Manufacturing industry	FSC	USA	Questionnaire survey				√				
Zhou & Benton (2007)	Manufacturing industry	FSC	USA	Pilot survey and formal questionnaire survey						√		
Chang & Tien (2006)	Construction industry	FSC	Taiwan	Questionnaire survey			√					
Gattiker & Goodhue (2005)	Manufacturing industry	FSC	USA	Questionnaire survey				√				
Hult, Ketchen & Slater (2004)	Transportation industry	FSC	Global	Pilot survey and formal questionnaire survey							√	
Flynn & Flynn (1999)	Manufacturing industry	FSC	USA, Germany, Japan, England, Italy	Questionnaire survey								√

As shown in Table 2.6, it is evident that many scholars have recurrently applied OIPT as the theoretical lens through which to explain different perspectives in the supply chain. For instance, some studies have used the theory to describe external and internal supply chain integration (Flynn, Koufteros & Lu 2016; Schoenherr & Swink 2012; Swink, Narasimhan & Wang 2007; Williams, BD et al. 2013; Wong, Boon-itt & Wong 2011); responses to supply chain disruption risks (Bode et al. 2011); the influence of information processing on the effectiveness of supply chain practices (Zhou & Benton, 2007); and the link between IT-enabled decision making and information integration (Wong et al. 2015; Wong, Wong & Boon-itt 2015).

As can be seen in Table 2.6, empirical studies on OIPT that relate to concerns in the construction industry are more scarce. However, some scholars have attempted to investigate epistemic uncertainties and equivocality in the FSC of the construction industry (Chang & Tien 2006; Levander et al. 2011). Interestingly, one recent study has focused on EoL coordination through the OIPT lens (i.e., van den Berg, Voordijk & Adriaanse 2020). In that study, the authors explored how demolition contractors coordinate EoL strategies, such as recycling and reuse of elements and components. According to the study, the building, the workflow and the environment are the epistemic uncertainties affecting these EoL strategies. Furthermore, the study discovered context-specific mechanisms in response to the identified epistemic uncertainties, three of which had not been disclosed by any previous study: ‘collection of drawings’, ‘on-site inspections’ and ‘prolongation of buyer collaboration’.

In summary, many previous studies have systematically adopted OIPT to explain different perspectives of FSCs, especially in the manufacturing industry. Even though OIPT originated with the aim of improving organisational performance, the above discussion verified that many scholars have successfully applied the theory in the supply chain context. However, previous studies have not attempted to apply OIPT to improve quality performance which is an essential measurement of organisational performance (Bhatti, Awan & Razaq 2014; Jayasinghe, Rameezdeen & Chileshe 2022). Furthermore, a paucity of studies has attempted to apply this theory to aspects of the RLSC, specifically in the construction industry context. All these knowledge gaps emphasise the originality and absolute need of investigation of the holistic view of information processing for QA in the dyadically configured RLSCs of DW based on the OIPT theoretical lens.

2.5.2 Information processing for QA in RLSCs of DW

Irrespective of the industry, previous studies have outlined that information is important to trigger QM efforts in any setting. These studies have revealed many enablers of QM related to information processing, such as information flow, information sharing and inter-firm communication in supply chains (Casadesús & de Castro 2005; Jayasinghe, Chileshe & Rameezdeen 2019; Lari 2002; Matta, Chen & Tama 1998; Sroufe & Curkovic 2008; Wijewickrama et al. 2021a; Xu 2011; Zeng, Lou & Tam 2007). For instance, the early study of Matta, Chen and Tama (1998) highlighted that globally reputed automobile manufacturing supply chains have used information sharing as a QA tool. These authors further mentioned that if useful information was available in a timely manner, especially on defective products, organisations could quickly undertake necessary precautions to rectify the defective products. Moreover, the issue and corresponding solution should be documented and entered into a database for future reference. As information is vital for QA, Lari (2002) developed a QA information system by analysing the information requirements of ISO 9000 standards. Zeng, Lou and Tam (2007) also showed that the information flow within a construction project is crucial for successfully implementing a QM system in the construction industry. Wang, C, Xu and Peng (2007) highlighted that supply chain quality efforts could be severely impacted due to the unavailability of useful information. Sroufe and Curkovic (2008) mentioned that the availability of useful information is one of the important enablers of quality improvement processes. In the context of RLSCs of DW, previous studies, as discussed in Subsection 2.4.1, provided evidence that the persuasive root cause for the inferior quality of reprocessed products is the poor information flow in supply chains (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe, Chileshe & Rameezdeen 2019; Wijewickrama et al. 2021a). Jayasinghe, Chileshe and Rameezdeen (2019) postulated that information and QM are key aspects that should be integrated to enhance RL performance. Moreover, Wijewickrama et al. (2021a) underlined the point that QA, an approach under QM, is not possible in the real-world context of RLSCs if information within the supply chain is not communicated multi-directionally. These authors posited that the aspects of process, people, policy and technology should be integrated to form the information-centric environment needed for QA in RLSCs of DW (see Subsection 2.4.2.3). From these findings, the current study develops the proposition that an information-centric environment is required for QA in RLSCs of DW.

However, as mentioned in Subsection 2.4.3, RLSCs of DW are deficient in useful information owing to the supply chain's fragmented, unorganised, cross-functional and multidisciplinary nature. This deficiency in useful information is the persuasive root cause of the inferior quality of reprocessed products in RLSCs of DW (see Subsection 2.4.1). The association between information deficiency and poor quality reprocessed products, as shown in Figure 2.5, can be explained in relation to the OIPT theoretical perspectives, as described in Subsection 2.5.1.

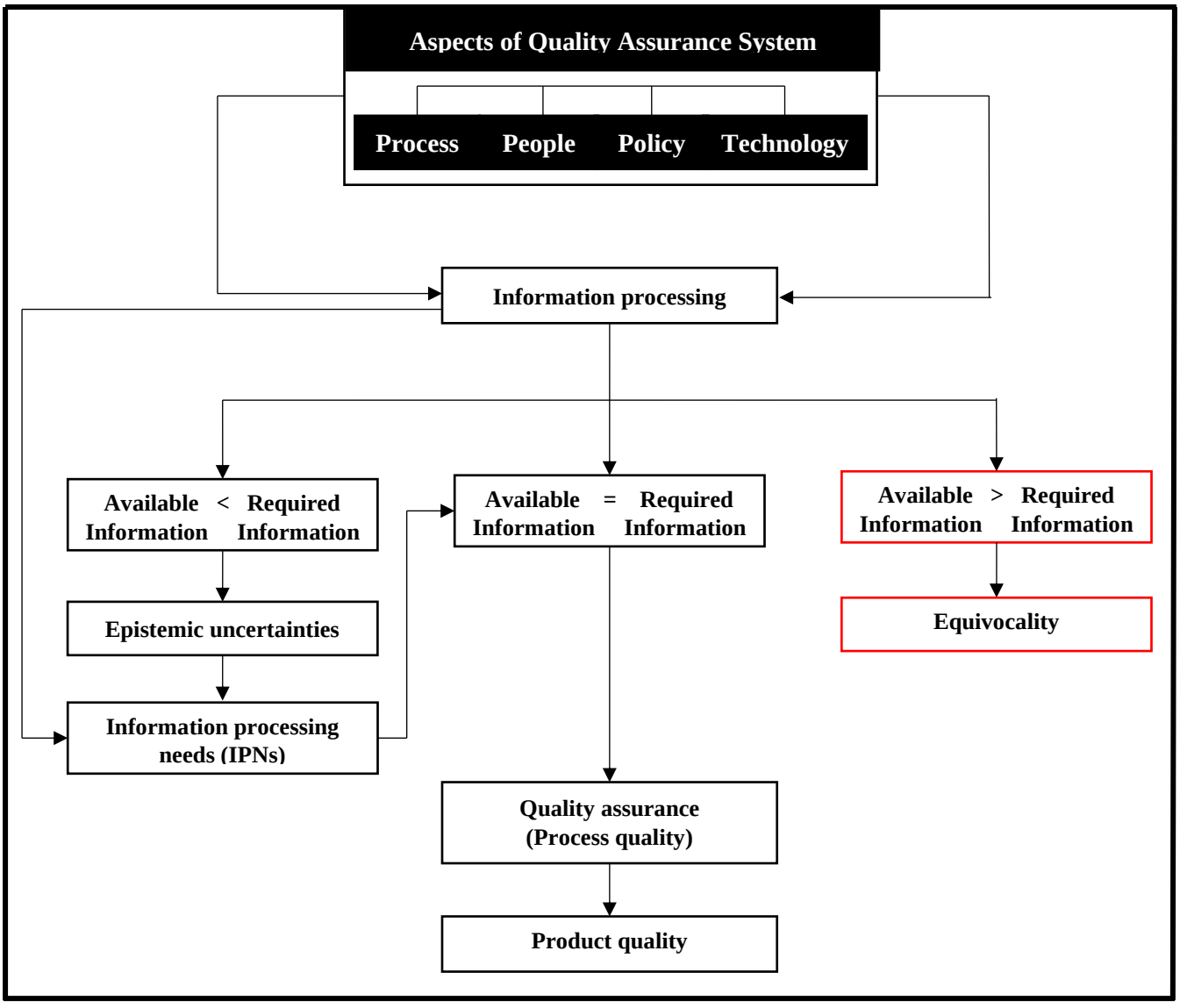


Figure 2.5. Information processing for QA

Accordingly, when each aspect of the QAS (i.e., process, people, policy and technology) is underperforming, the required useful information for QA would not be processed and shared between the other aspects, thus creating information deficiencies. According to OIPT, the situations in which the useful information needed to perform a task is less than the available information are known as epistemic uncertainties (see Subsection 2.5.1). These epistemic uncertainties will lead to IPNs (Galbraith 1973, 1974). Therefore, in response to these IPNs, the organisations (i.e., demolishers and waste processors) in RLSCs of DW should process useful information by undertaking appropriate IPMs developed by making aspects of the QAS more robust. When IPNs match the information processed through these mechanisms, the RLSCs of DW, through effective QA, could yield quality reprocessed products. As none of the previous studies to date have empirically established the holistic view of information processing for QA in RLSCs of DW, the current study is a progression in this direction.

2.6 Need for an Information Processing Model for QA in RLSCs of DW

The epistemic uncertainties of a supply chain could originate from multiple levels in the organisation, namely, macro-, meso- and micro-levels (Flynn, Koufteros & Lu 2016; Xu & Song 2022). Macro-level uncertainties stem from the ineffective external environment's influence; micro-level uncertainties from the internal organisational environment; and meso-level uncertainties due to interactions with stakeholders within the supply chain. Previous studies highlighted that epistemic uncertainties do not exist in isolation but have interactions (Bhatnagar & Sohal 2005; Busse, Meinlschmidt & Foerstl 2017; de Vasconcelos Gomes et al. 2018; Gales, Porter & Mansour-Cole 1992; Khanmohammadi 2021; Peidro, Mula & Poler 2007). For instance, in their early study, Gales, Porter and Mansour-Cole (1992) mentioned that in an innovation project, even if a few epistemic uncertainties exist at the project's start, they accumulate and form new uncertainties at the time of the project's implementation. As found by de Vasconcelos Gomes et al. (2018) in their empirical study, epistemic uncertainties become collective due to propagation and affect the firm's performance. In the supply chain context, Bhatnagar and Sohal (2005) asserted that epistemic uncertainties always 'tend … to propagate up and down the supply chain, and this affects supply chain performance' (p. 444). With a similar argument, Rezapour, Allen and Mistree (2015) stated that:

> … uncertain output of [a] supplier is input to the manufacturer who also has an uncertain manufacturing system. Thus uncertainty of the manufacturer's system is added to its uncertain input level which leads to a greater uncertainty in its qualified output. (p. 187)

On this note, it is understandable that, despite various classified epistemic uncertainties, they would not appear as distinct levels but by forming cause-and-effect relationships in how they interact. These epistemic uncertainties could propagate from one level to another or up and down along the supply chain (Busse, Meinlschmidt & Foerstl 2017; Peidro, Mula & Poler 2007). In general, the cause-and-effect relationships reflect the propagation of variables to exert a systemic effect on the operational performance criterion of the study (Jayasinghe, Rameezdeen & Chileshe 2022), as shown in Figure 2.6. The systemic effect is defined as 'formal, affecting the whole of something' (Summers, D 2003, p. 1685). Given this, the systemic effect of epistemic uncertainties reflects their collective chain reaction or propagation effect on a performance measurement criterion.

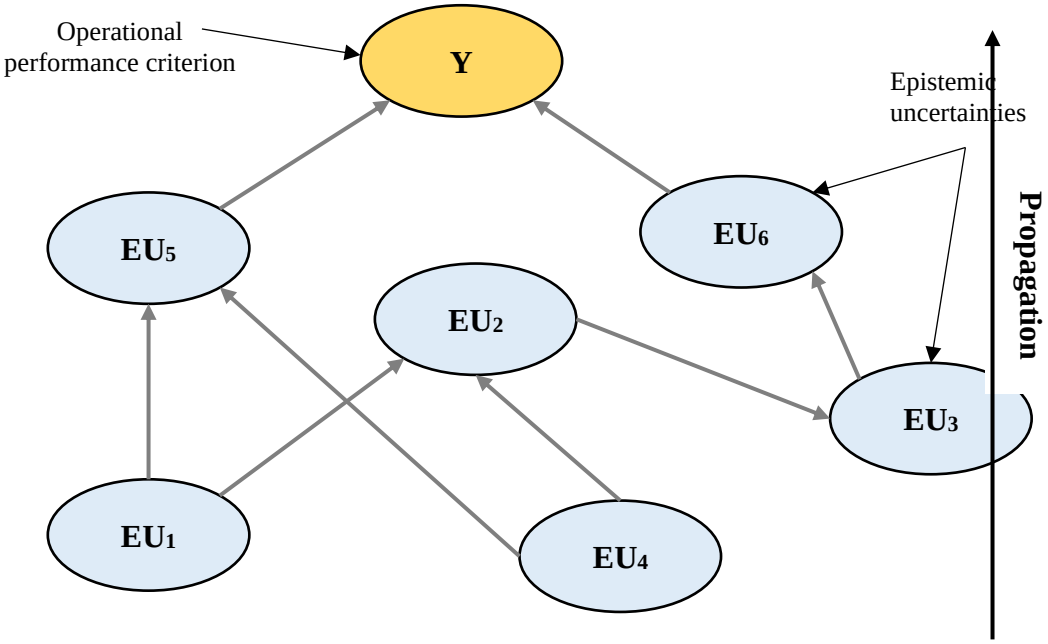


Figure 2.6. Cause-and-effect relationships between epistemic uncertainties (EUs)

As mentioned above, even if studies found that epistemic uncertainties do not exist in isolation but have cause-and-effect relationships, none of the previous studies have attempted to identify these relationships in any context. Congruently, Flynn, Koufteros and Lu (2016) called for a future study on the different types of epistemic uncertainties encountered by a supply chain and their potential interactions. As explained in Subsection 2.5.2, RLSCs of DW encounter epistemic uncertainties which adversely

affect QA in supply chains. As these epistemic uncertainties create cause-and-effect relationships, they undeniably should exert a propagation effect on QA, with the propagation effect of variables, such as epistemic uncertainties, in the current study able to be represented as a model (Jayasinghe 2019; Leong 2018; Peidro et al. 2009). To develop the model, the epistemic uncertainties for QA and the IPMs that could be undertaken in response should first be identified, having not previously been identified by an empirical study. After this, the causal relationships between epistemic uncertainties should be identified to develop a causal map that could be used to quantitatively model these causal relationships (Chapter 3, Subsection 3.5.2.2.1 explains the process followed in developing the causal map in the current study). None of the previous studies has provided a holistic view of information processing for QA in RLSCs of DW by identifying the epistemic uncertainties for QA, their cause-and-effect relationships and the IPMs that could be undertaken in response., By addressing these gaps in the literature, the current study aims to develop and empirically validate an information processing model for QA in RLSCs of DW.

2.7 Knowledge Gaps

The literature review above identified several knowledge gaps in the context of RLSCs of DW. These gaps are consolidated and briefly discussed in the following subsections.

2.7.1 No empirical insights have established how process, people, policy and technology contribute to QA in RLSCs of DW

The current study's literature review revealed that quality issues in reprocessed products prevent them from being used in new constructions (Chileshe et al. 2015; Chileshe et al. 2016; Pushpamali, Agdas & Rose 2020; Wijewickrama et al. 2021a). Consequently, inferior-quality reprocessed products impede successful RLSC implementation in the construction industry (Chileshe, Rameezdeen & Hosseini 2016; Pushpamali, Agdas & Rose 2020). The quality of the final product depends on the quality of the process employed in its production (Nikolaidis 2012; Sheikh et al. 2019; Thakur 2010). Therefore, QA, which focuses on improving process quality (Keist 2015; Nikolaidis 2012), plays an essential role in producing quality output in RLSCs of DW (Wijewickrama et al. 2021a). Wijewickrama et al. (2021a), through an SLR, found that QA in RLSCs of DW should be an integrated system of four aspects: process, people, policy and technology. However, no study, to date, has empirically established how

these aspects contribute to QA in RLSCs of DW, with the SLR by Wijewickrama et al. (2021a) raising the need for this to be a topic for future study. Therefore, the first objective of the current study is to progress towards addressing this knowledge gap.

2.7.2 Unrecognised epistemic uncertainties lead to IPNs and corresponding IPMs for QA in RLSCs of DW

Previous studies asserted that the availability of useful information is a prerequisite for any QM effort, including QA in a supply chain (Casadesús & de Castro 2005; Jayasinghe, Chileshe & Rameezdeen 2019; Lari 2002; Matta, Chen & Tama 1998; Sroufe & Curkovic 2008; Wijewickrama et al. 2021a; Xu 2011; Zeng, Lou & Tam 2007). Congruently, Wijewickrama et al. (2021a) revealed that an information-centric environment is needed to integrate the aspects of process, people, policy and technology of QAS in RLSCs of DW. However, as RLSCs of DW have not had the benefit of a well-organised information flow (Chileshe, Jayasinghe & Rameezdeen 2019), the useful information needed for QA is deficient within the supply chain (Jayasinghe, Chileshe & Rameezdeen 2019; Rahimi & Ghezavati 2018). If the required useful information is unavailable for making decisions, epistemic uncertainties arise, leading to IPNs in an entity (Brugnach et al. 2008; Galbraith 1973, 1974; Khanmohammadi 2021; Walker et al. 2003). Correspondingly, Rahimi and Ghezavati (2018) emphasised that uncertainties appear in RLSCs of DW due to information deficiency, negatively affecting the supply chain's quality efforts. As further postulated by OIPT, appropriate IPMs should be undertaken in response to epistemic uncertainties so that organisational or supply chain performance will be achieved (Busse, Meinlschmidt & Foerstl 2017; Foerstl, Meinlschmidt & Busse 2018; Galbraith 1973, 1974; Tushman & Nadler 1978; van den Berg, Voordijk & Adriaanse 2020). These IPMs could be either IPN-reducing or IPC-increasing mechanisms (Foerstl, Meinlschmidt & Busse 2018; Galbraith 1973, 1974). Despite the application of OIPT theoretical perspectives in many context-specific studies, none of these studies have identified the epistemic uncertainties that lead to IPNs for QA and the IPMs that respond to these epistemic uncertainties in the context of RLSCs of DW. Therefore, the current study's second objective is to fill the knowledge gap in the existing literature related to the unrecognised epistemic uncertainties that lead to IPNs and the corresponding IPMs for QA in RLSCs of DW.

2.7.3 No investigation has been undertaken on information processing for QA in RLSCs of DW

Previous studies elucidated that epistemic uncertainties in a supply chain do not appear to be distinct at macro, meso and micro levels, but they do have interactions (Bhatnagar & Sohal 2005; Busse, Meinlschmidt & Foerstl 2017; de Vasconcelos Gomes et al. 2018; Gales, Porter & Mansour-Cole 1992; Khanmohammadi 2021; Peidro, Mula & Poler 2007). The interdependencies of epistemic uncertainties facilitate uncertainty propagation analysis to derive their systematic effect on the operational performance criterion, which is QA in RLSCs of DW in the current study. However, the interdependencies between epistemic uncertainties, to date, have not been established in any context. On this note, Flynn, Koufteros and Lu (2016) highlighted that:

> Finally, there may be multiple levels of uncertainty …, such as task, strategic, and environmental uncertainty, embedded within the broader constructs of micro-level, meso-level, and macro-level uncertainty. Future research should differentiate between the types of uncertainty that a supply chain member faces, as well as potential interactions between them. (p. 24)

To the best of the researcher's knowledge, this is the first study to develop an information processing model visualising the interdependencies of epistemic uncertainties while computing their propagation and systematic effect on QA in RLSCs of DW. Of interest in this attempt is that the model also included the IPMs that respond suitably to the epistemic uncertainties to provide a holistic understanding of information processing for QA in RLSCs of DW. The study's final two objectives facilitate bridging the knowledge gap in the extant literature that arises due to no investigation having been undertaken on information processing for QA in RLSCs of DW.

2.8 Concluding Remarks

This chapter presented the state-of-art review of information processing for QA in RLSCs of DW. The chapter first introduced an RLSC of DW by comprehensively explaining each of its phases. The chapter then expands and discloses the barriers that inhibit the successful implementation of RLSCs of DW. Of all the barriers, the study focused on two significant barriers (i.e., poor quality of reprocessed products and information deficiency) and indicated the relationship between them. With this foundational base, the study identified a few knowledge gaps in the extant literature, thus justifying the purpose of the current study. As discussed in the chapter, the RLSC of DW is an understudied area in the current literature, in comparison to research on the

FSC in the construction industry. The chapter identified the need to empirically establish how aspects of process, people, policy and technology contribute to QA in RLSCs of DW. Similarly, based on the OIPT's theoretical perspectives, this chapter highlighted the necessity of identifying epistemic uncertainties that lead to IPNs for QA and the IPMs that respond to these epistemic uncertainties in the context of RLSCs of DW. The chapter concluded by signalling the need to develop an information processing model that visualises the interdependencies of epistemic uncertainties while computing their propagation and systematic effect on QA in RLSCs of DW. The next chapter discusses the research methods followed to address the knowledge gaps identified in the extant literature.

3 Research Methodology

3.1 Introduction

This chapter discusses the research methodologies used to achieve the research aim and objectives formulated in the current study. Initially, it lays out the research setting, along with the choice of research design. It then discusses the chosen research approach and methods, including the data collection and analysis methods. Finally, it explains the ethics considerations of the study.

3.2 Research Setting

According to Lune and Berg (2017), a research setting should be a location or site where access is possible, appropriate people are available and, especially, the focused processes, people and interactions of the study are accessible to the researcher. Similarly, Durdella (2017) mentioned that, when selecting the research setting, the researchers need to consider the appropriateness of the location to the research purposes and, most importantly, the researchers' existing connections and easy accessibility to the site. The current study aimed to fill the gaps in the existing literature rather than searching for solutions to practical problems within a particular setting; thus, it was not site-specific research and could be conducted in many potential settings (Marshall & Rossman 2014). Considering these points, the DW management industry in the South Australian context appeared appropriate for achieving the research aim and objectives presented in Chapter 1.

South Australia (SA) is one of the most promising states in Australia regarding waste management practices. The state is renowned globally due to its leadership in innovative CDW management, execution of excellent best practices and enactment of environmental legislative reforms to create a cleaner state (GISA 2020; Pickin et al. 2020). In 2018–2019, Australia generated more than 27 million tons of CDW,

contributing nearly 44% of the aggregate waste generated in the country (Pickin et al. 2020). Furthermore, these authors mentioned that SA was the highest-ranked jurisdiction among all states in Australia for waste management, with a waste recycling rate of 80%. Moreover, this state had the highest landfill diversion rate for CDW, at 91.4% in 2020, which was expected to increase by a further 5% at the end of 2025 (GISA 2020). Furthermore, H Wu et al. (2020) found that SA acted as a centre for waste reprocessing/recycling in Australia; thus, several other states transported their waste to this state for reprocessing/recycling. Due to these points, this state has the potential grounds to be a source of experts with the experience and knowledge required to ensure the highest process quality in RLSCs by successfully dealing with epistemic uncertainties. Therefore, conducting this study within such a context helped to yield a wealth of knowledge due to the state's maturity, history and experience in DW management. Furthermore, as this was the state where the researcher was based, she had some connections and accessibility to potential experts in the setting under research. Therefore, SA was selected as the study's research setting for data collection.

3.3 Choice of Research Design

Abutabenjeh and Jaradat (2018) explained the research design as follows:

> A blueprint to guide the research process by laying out how a study will move from the research purpose/questions to the outcomes. (p. 238)

As these authors further elucidated, a research design provides a comprehensive framework that indicates the plan and procedure used to collect and analyse data to address the research questions. According to Punch (2014, 2016), a research project could be designed following either the paradigm-driven or the pragmatic approach. In the former approach, a research paradigm is chosen based on philosophical assumptions of ontology and epistemology, and appropriate research questions and methods are then developed, aligned with the paradigm. In the pragmatic approach, on the other hand, research questions are first formulated and the data collection and analysis methods are then selected to address these questions.

Even if framing the research design based on the study's philosophical underpinnings is more popular in research, many previous studies continued to highlight the viability of choosing the research design based on the pragmatic approach rather than the paradigm-driven approach. For instance, Sackett and Wennberg (1997) indicated that:

> The question being asked determines the appropriate research architecture, strategy and tactics to be used—not tradition, authority, experts, paradigm or school of thoughts. (p. 1636)

Furthermore, Gorard and Taylor (2004) suggested that the methodology should be chosen based on the situation and the research questions rather than the researcher's personality, skills and ideology. In the same vein, Bryman (2003) proposed that the choice of methodology should be a technical, not an epistemological, decision. In the same vein, White (2017) argued that researchers do not need to know philosophical underpinnings to decide upon the research design for meaningful social research. Therefore, the current study was driven by the pragmatic approach in which the research design, as shown in Figure 3.1, was determined based on the research questions, rather than on philosophical debates.

According to Mattick, Johnston and de la Croix (2018), a research question is 'a question that a research project sets out to answer' (p. 104). Sandberg and Alvesson (2011) raised the importance of constructing innovative research questions to address the gaps, problems or topics identified through the existing literature. The research questions lay out the specific queries to be addressed under a study's objectives (Frechette et al. 2020; Parraguez 2015; Reynolds & Guest 2015). As explained in Chapter 1, Section 1.4, four sub-research questions were constructed in the current study, as per the neglect gap spotting mode explained by Sandberg and Alvesson (2011). These research questions were directed toward deciding upon the research approach and the data collection and analysis methods of the study, as shown in Figure 3.1 and explained in the following sections, along with justifications for their selection.

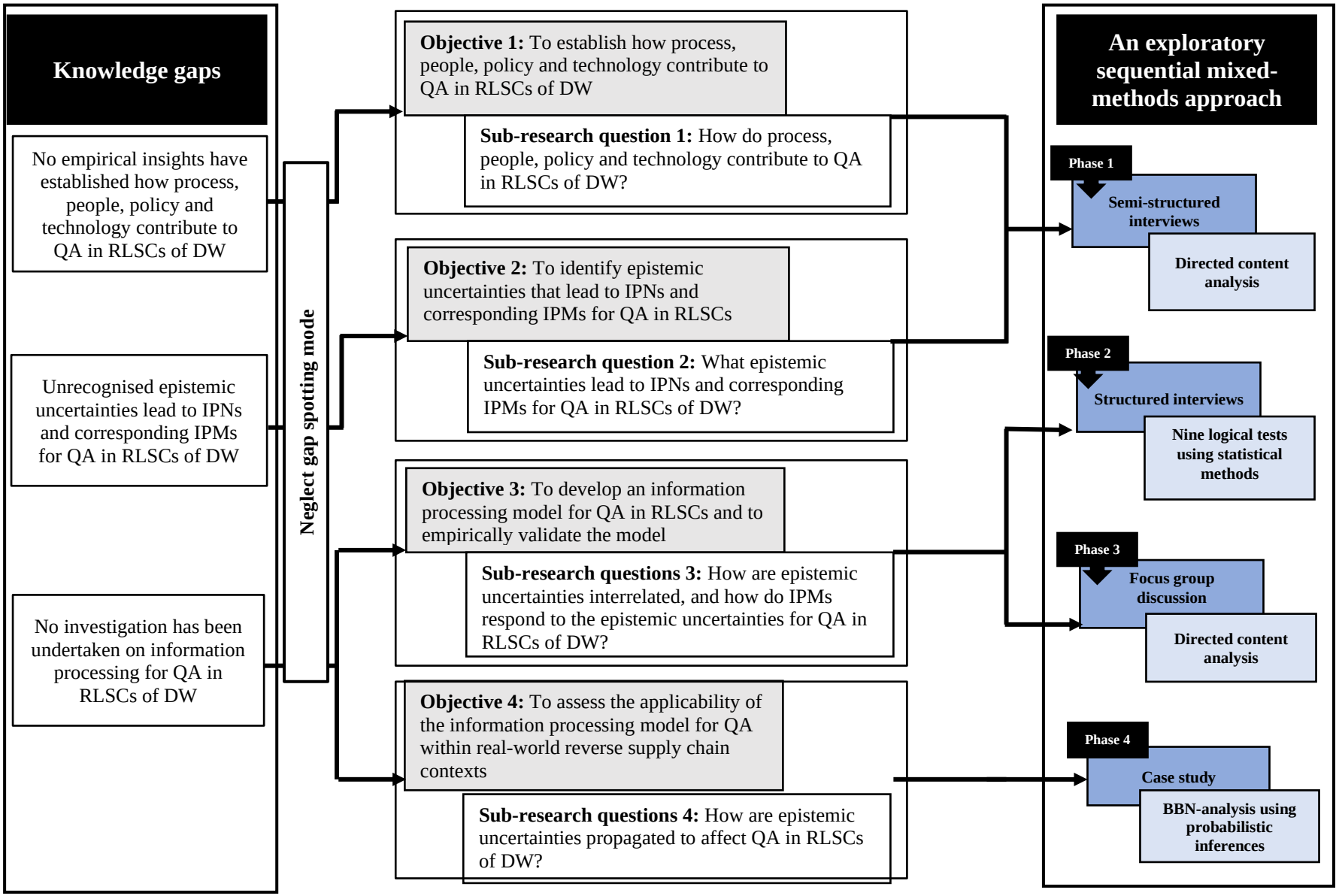


Figure 3.1. Research design

3.4 Research Approach

According to Creswell (2015), the three research approaches are quantitative, qualitative and mixed methods. In essence, the quantitative approach is subjective and well suited to examining the relationship between quantifiable variables, with analysis through different statistical and graphical techniques (Bryman 2006; Saunders, Lewis & Thornhill 2019). On the other hand, the qualitative approach is objective in nature. It helps to gain an in-depth and exploratory understanding of a context or setting, especially considering the views and perspectives of people in that setting (Yin 2017). In some research, qualitative and quantitative approaches are used in combination to overcome the inherent weaknesses of using only one of these approaches. This combined approach is known as a mixed-methods approach (Bryman 2006; Saunders, Lewis & Thornhill 2019).

Previous studies stated that the choice of the research approach depends upon the study's research questions (Fellows & Liu 2015; Ghauri 2004; Saunders, Lewis & Thornhill 2019). The primary research question that the current study aimed to answer was 'How is information processed, in response to the epistemic uncertainties that lead to IPNs, for QA in RLSCs of DW?' Additionally, the study had four sub-research questions that laid out the specific queries to be addressed under each objective, as shown in Figure 3.1. Prior research revealed that exploratory studies, which often start with 'what' and 'how' research questions (Creswell & Creswell 2017; Leavy 2017; Saunders, Lewis & Thornhill 2019), are appropriate for laying the initial groundwork for the study by exploring the issue, problem or phenomenon being researched (Leedy & Ormrod 2015; Saunders, Lewis & Thornhill 2019). Accordingly, to address this study's first sub-research question, an exploratory study was required to establish the 'how' aspects of the process, people, policy and technology contributions to QA in RLSCs of DW. As the notion of the RLSC is an underdeveloped area in the construction industry (Pushpamali et al. 2021; Trochu, Chaabane & Ouhimmou 2020), the current study also sought an exploratory insight into the epistemic uncertainties that lead to IPNs and corresponding IPMs for QA in RLSCs. According to Saunders, Lewis and Thornhill (2019), exploratory studies are often conducted with a qualitative approach using methods such as a literature review, in-depth interviews and/or focus group discussions. Consequently, in the first phase, this study employed an exploratory

qualitative approach by conducting semi-structured interviews (see Subsection 3.5.1.1) to answer the initial two sub-research questions which sought to address the study's first two objectives.

As mentioned by Saunders, Lewis and Thornhill (2019), an explanatory study establishes causal relationships between variables by answering research questions that begin with 'why' and 'how'. Given this point, once the groundwork was established in the current study, an explanatory quantitative approach was used in the second phase to address the third sub-research question, 'How are epistemic uncertainties interrelated, and how do IPMs respond to the epistemic uncertainties for QA in RLSCs of DW?' In addressing this research question, the study developed an information processing model for QA in RLSCs of DW. Subsequently, in the third phase, this model was empirically validated using a qualitative approach by conducting a focus group discussion. Saunders, Lewis and Thornhill (2019) stated that evaluative studies determine how well an instrument (strategy, policy, program, process, model or framework) works by assessing the effectiveness of its application. Accordingly, research questions that seek to evaluate answers often begin with 'how' and 'what' in the form of 'to what extent' and can be addressed through a quantitative approach. As this study needed an evaluative study to address the final sub-research question 'How are epistemic uncertainties propagated to affect QA in RLSCs of DW?', a quantitative approach was followed in the fourth phase.

As explained above, the current study used a mixed-methods approach to sequentially conduct exploratory, explanatory and evaluative studies. According to Creswell (2015), research with an exploratory sequential mixed-methods approach

> … begins by collecting and analyzing qualitative data. From this analysis, the researcher uses the results to develop something quantitative such as an instrument or an intervention—and then in the final phase of the research, the investigator applies or tests the quantitative instrument or intervention. (p. 64)

By following this procedure, the current study therefore adopted 'an exploratory sequential mixed-methods approach', as shown in Figure 3.1. Creswell (2015) mentioned that this research approach firstly intends to explore as knowledge in the existing literature is insufficient for studying a population or concepts, with this being similar to the current study's context. According to Mason (2006), when mixed research methods are used, this has huge potential for generating new ways of understanding the

complexities in the research setting and for enhancing the strength and generalisability of findings by enabling triangulation. Most importantly, Saunders, Lewis and Thornhill (2019) indicated that this approach evades the cons inherent in single approaches and increases confidence in the research findings and conclusions. The data collection and analysis methods addressing each sub-research question are explained next.

3.5 Research Methods

As discussed in Sections 3.3 and 3.4, the current research employed an exploratory sequential mixed-methods approach. Creswell (2015) observed that, in the sequential design of the mixed-methods approach, two or more research methods representing different research approaches are implemented, with one preceding the other at different periods. Figure 3.2 illustrates the sequential phases of the qualitative and quantitative data collection and analysis methods used in the current research.

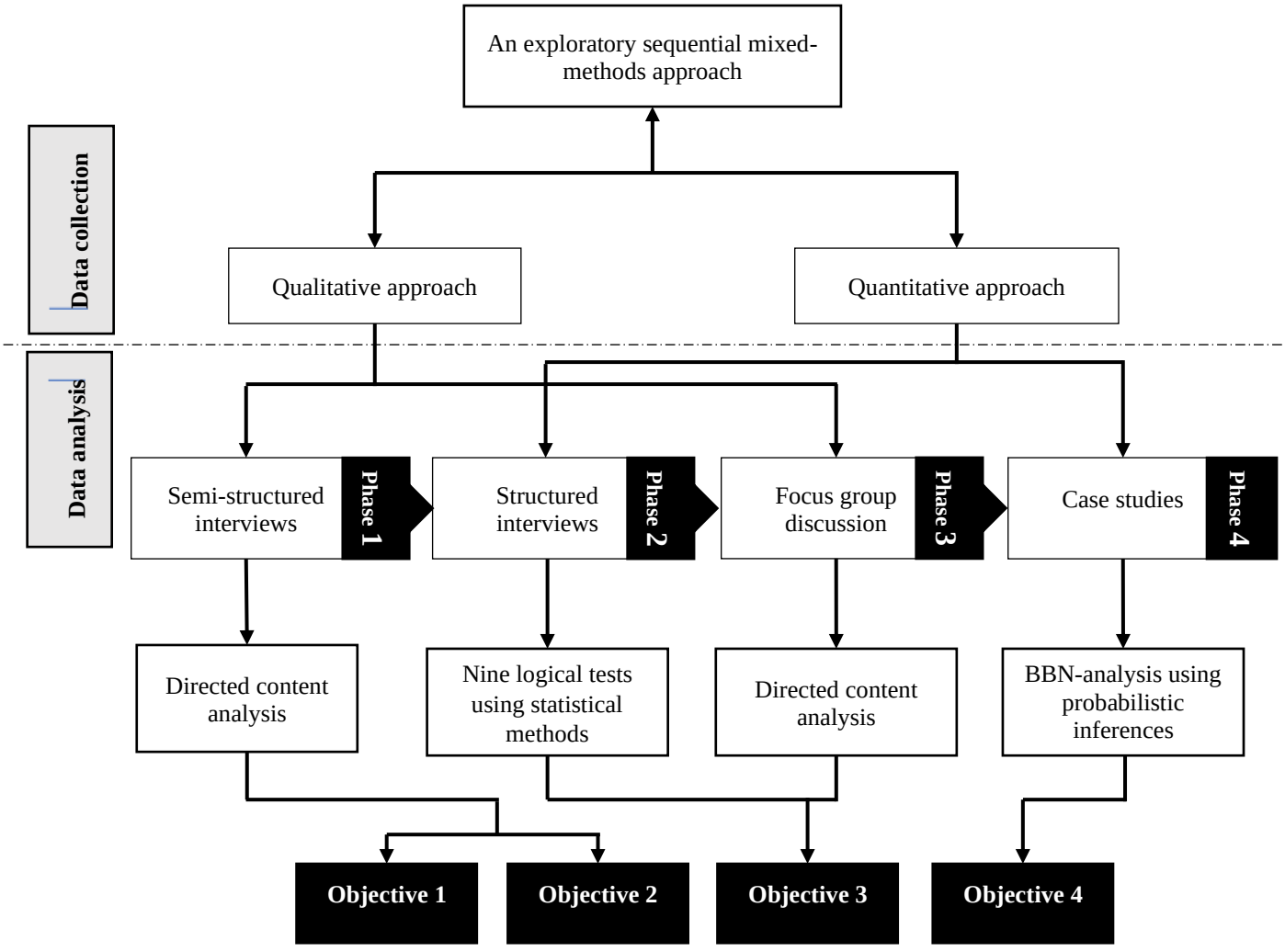


Figure 3.2. Research methods

As shown in Figure 3.2, the sequential arrangement of the research methods in the current study is primarily decided based on previous studies. These have used the BBN-modelling technique to provide insights from propagation analyses of different aspects of supply chain management, such as risks in supply chains (Badurdeen et al. 2014; Jayasinghe 2019; Leerojanaprapa 2014; Luu et al. 2009; Qazi et al. 2018); uncertainty aggregation (Leong 2018; Nannapaneni, Mahadevan & Rachuri 2016); and safety analysis (Babaleye, Kurt & Khan 2019; Feng, Jiang & Wang 2020). The following subsections provide a detailed explanation of each of these data collection and analysis methods.

3.5.1 Data collection methods

Table 3.1 summarizes the data collection methods used in all four phases of the research design, including information on the nature of the participants involved and their respective sample sizes.

Table 3.1. Summary of data collection methods

	Data collection method	Nature of participants involved	Sample size
Phase I	Semi-structured interview	Internal and external stakeholders of the RLSCs of DW in SA	30
Phase II	Structured interviews	Experts (minimum of 10 years of experience) in the DW management sector, representing building dismantling and on-site processing and off-site waste processing phases in SA	20
Phase III	Focus group discussion	Experts (minimum of 10 years of experience) in the DW management sector, representing building dismantling and on-site processing and off-site waste processing phases in SA	5
Phase IV	Case studies (2 cases)	Experts (minimum of 15 years of experience) in the DW management sector, representing building dismantling and on-site processing and off-site waste processing phases in SA	4 in Case I and 3 in Case II

The internal stakeholders who participated in all data collection phases represented the managerial roles in their respective organizations. When considering the internal stakeholder categories, managers are saddled with the responsibility of leading their organizations by making effective and efficient decisions that will communicate to the operational level workers to undertake (Abubakar et al. 2019). To make these decisions, managers require not only versatility and prowess but useful information regarding the internal and external environment of the organization (Abubakar et al. 2019; Hugos 2018; Steiss 2019). Therefore, managers are the best internal stakeholder category to know than operational level workers what information they require, whether such information exists or does not exist within their organizations, and if not exist, what mechanisms to undertake to process the required information. Furthermore, Harris et al. (2021) mentioned that QA is often initiated by management as they realize that it is significant for the organization to be competitive in the industry. Given all these facts, incorporating participants representing managerial roles in the RL industry for the current study is admissible.As explained in Sections 3.3 and 3.4, this research employed an exploratory sequential mixed-method approach, including four phases of data collection. All these four phases of data collection were conducted in SA with valid justifications, as explained in Chapter 1, Section 1.5 and Chapter 3, Section 3.2. Furthermore, only the respondents who represented the managerial positions were incorporated into this study with coherent justifications, as explained in Subsection 3.5.1. However, when conducting this research with these valid limitations, the candidate encountered a serious challenge in recruiting respondents since the population of the current study was small, not easily reachable and responsive. This challenge was further compounded by the COVID-19 pandemic, which peaked during the data-collection period of the study. Therefore, with these practical issues and the time constraints, the candidate had to recruit a few cooperative and responsive respondents in more than one data collection phase. This was not considered an issue because there is no definite consensus on using the same or different participants in mixed methods research in the current body of literature. For instance, Wisdom and Creswell (2013) revealed that one of the core characteristics of a well-designed mixed-method study is ‘using procedures that implement qualitative and quantitative components either concurrently or sequentially, with the same sample or with different samples’ (p. 1). Given this, there is a common practice among researchers to use the same participants for different phases of data collection in mixed-method research (Creswell & Clark

2018; Wisdom & Creswell 2013). In addition, when considering only the validation phase, which is the focus group discussion, Qazi et al. (2018) pointed out that to empirically validate a BBN-based conceptual model, the focus group needs to involve participants from the previous phase in which the model was developed and some new experts from the industry. Considering all these facts, a few respondents were repeatedly involved in more than one data collection phase in the current study, which is considered acceptable.

3.5.1.1 Phase 1: Semi-structured interviews

The first phase of the research was carried out based on the qualitative approach using semi-structured interviews. The purpose of conducting semi-structured interviews was to establish how process, people, policy and technology contribute to QA (Objective 1 [OBJ.1]) and to identify the epistemic uncertainties that lead to IPNs and corresponding IPMs for QA in RLSCs of DW (Objective 2 [OBJ.2]). More than 30 years ago, Burgess (1984) defined an interview as a 'conversation with a purpose' (p. 102). However, even today, interviews have striking popularity among qualitative researchers in various disciplines (Fischer & Guzel 2022; Hitchings & Latham 2020) as they represent 'the gold standard of qualitative research' (Silverman 2000, pp. 291-292). As highlighted by Cohen, Manion and Morrison (2002), interviews effectively explore in greater depth and validate the facts raised by other research techniques, enriching the research by generating qualitative data. Accordingly, the interviews conducted in the current study first established how aspects such as process, people, policy and technology identified in the SLR by Wijewickrama et al. (2021a) contribute to QA in RLSCs of DW, adding additional insights to the context through empirically generating qualitative data. Furthermore, Saunders, Lewis and Thornhill (2019) highlighted that interviews advocate in-depth and in-breadth examination of an issue that has not previously been completely investigated in a certain setting. Interviews facilitate discussion with interviewees of their experiences and interpretations of the particular phenomenon about which the interviewer is inquiring (Winwood 2019). On this note, the interviews conducted in the first phase of this study were also used to identify epistemic uncertainties that lead to IPNs and corresponding IPMs for QA in RLSCs of DW.

Interviews can be structured, unstructured or semi-structured; however, the latter is the most common (Eppich, Gormley & Teunissen 2019). Structured interviews comprise a pre-determined set of questions to obtain specific data points that lead to quantitative

analysis (Alshenqeeti 2014). Unstructured interviews facilitate a free and general discussion around the issue under investigation (Saunders, Lewis & Thornhill 2019). From each discussion, the researcher picks up important facts and pursues them more deeply as they emerge. Semi-structured interviews are the middle of this interview continuum and are the most widely used data collection method in qualitative studies (Eppich, Gormley & Teunissen 2019). In semi-structured interviews, the interviewer asks each interviewee the same set of pre-planned questions; however, he/she is free to ask emergent questions or to probe further on points that arise from their conversation (McIntosh & Morse 2015). This type of interview allows the researcher to adapt the interview questions as necessary depending on the situation to elucidate lack of clarity or doubt in interviewees' responses and to ensure that the given response is clearly understood and, if not, to repeat and/or recap the questions (Winwood 2019). Therefore, in contrast to structured interviews, semi-structured interviews permit adequate flexibility to approach diverse respondents differently while covering the same areas of data collection. Winwood (2019) further revealed that many of the benefits of semi-structured interviews are compounded if undertaken in person, allowing the interviewer to gather non-verbal responses from interviewees. Considering all these points, semi-structured interviews were considered appropriate for this data collection phase.

In light of this, 30 semi-structured interviews were conducted with internal and external stakeholders in RLSCs of DW in SA as the first phase of the study's data collection. All interviewees had a minimum of eight years of experience in the construction industry's waste management sector and held senior positions in their organisations. The quality of data collected from semi-structured interviews was improved by incorporating experienced and knowledgeable interviewees (Lin et al. 2019) who showed their interest in taking part in the study (Simms & Rogers 2006). In all, 24 interviews were conducted with internal stakeholders in RLSCs of DW representing the building dismantling and on-site processing phase and the off-site waste processing phase. The remaining interviews were conducted with external stakeholders who represented the regulatory sectors. These external stakeholders were not directly involved in the RLSC operations (Brandão et al. 2021b) but were entitled, through regulations, to influence the supply chain setting, its operations and QA procedures (Brandão et al. 2021b; Jayasinghe, Chileshe & Rameezdeen 2019; Wijewickrama et al. 2021a). As observed in prior studies, external stakeholders have a broad understanding of the processes undertaken in

the supply chain (Wijewickrama et al. 2022). Furthermore, these authors found that, as external stakeholders were peripheral to the internal supply chain, unlike internal stakeholders, they had no hesitation in pointing out existing supply chain deficiencies. Thus, incorporating internal and external stakeholders ensured adequate foundations were built for the context behind information processing for QA in RLSCs of DW.

The purposive sampling method was used to recruit interviewees for the semi-structured interviews. According to McIntosh and Morse (2015), purposive sampling methods help identify the most appropriate respondents for a study, maximising the depth and richness of the data to address the research questions. From all the purposive sampling techniques, such as snowball, convenience, homogenous and variable (McIntosh & Morse 2015; Saunders, Lewis & Thornhill 2019), the snowball sampling technique was chosen in the current study to recruit interviewees. According to Mweshi and Sakyi (2020), the snowball sampling technique increases the degree to which the sample is representative of populations that are not easily approachable. Therefore, with this technique, subsequent interviewees are incorporated into a study from the information provided by the initial interviewees (Naderifar, Goli & Ghaljaie 2017; Saunders, Lewis & Thornhill 2019). Accordingly, as the population of the current study was not easily reachable and responsive, 11 seed interviewees were initially interviewed to begin the referral chain for the remaining interviewees.

The sample size of a qualitative study becomes trivial when data quality is rich (Simms & Rogers 2006). Although qualitative studies are always being criticised for small sample sizes, Smith (2018) commented that ‘rich knowledge and small samples purposefully chosen are thus unique strengths of qualitative research, not weaknesses’ (p. 139). According to Simms and Rogers (2006), the concept of ‘saturation’ determines the sample size of a qualitative study, with this concept referring to the point at which no new data are available to enhance or change the study’s extant findings. Correspondingly, the interviews in the current study were conducted until no new themes were derived from the last two interviews to add to what had been found from the initial interviews. Subsequently, data saturation in the current study was achieved after conducting 30 interviews. This number of interviews was within the acceptable range of sample sizes that previous studies had declared adequate for reaching saturation in a qualitative study (Mason 2010; Thorne 2020).

The interview guideline was prepared, comprising questions to obtain demographic data and on how process, people, policy, technology and information contribute to QA in RLSCs (see Appendix 1[C]). Interviewees were encouraged to provide practical examples in their responses to the questions. In addition to the pre-determined questions, probing questions were asked when necessary to obtain a holistic understanding of the research area (McIntosh & Morse 2015). During the interviews, the researcher did not use terms, such as 'epistemic uncertainty' and 'IPMs', assuming that interviewees would be uncomfortable with those theory-based terminologies. Even if questions were asked about the availability and unavailability of information for QA, some interviewees were unable to answer as they could not immediately recall the circumstances in which they had encountered information deficiencies. Codó (2008) stated that:

> One important weakness of interviews is that there may be limits to the amount and kinds of details the researcher is able to gather. (p. 162).

In these circumstances, Codó (2008) highlighted that, instead of asking direct questions, what

> researchers can do is try to modify interviewees' perception of the event as more or less formal and of the relationship with their interlocutor. (p. 164)

Apart from direct questions about information deficiencies, indirect questions were asked about barriers to QA and the measures that could be undertaken to overcome these barriers. With this approach, interviewees became more relaxed and confident in answering. At the same time, the researcher was able to indirectly distinguish the epistemic uncertainties and IPMs for QA in RLSCs of DW.

The COVID-19 pandemic disrupted the conducting of semi-structured interviews; thus, they were held over a longer time frame than anticipated (i.e., from September 2020–May 2021). Due to the pandemic, 13 interviews were conducted virtually via Microsoft Teams and Zoom, while a face-to-face approach was used for the remaining interviews. The interviews were conducted in line with ethics considerations and protocols, with no issues reported. Each interview lasted between 45 min and 60 min, with interviews recorded with interviewees' consent. As mentioned by Saunders, Lewis and Thornhill (2019), as interviews were audio recorded, the researcher was able to concentrate more on interviewees, maintaining eye contact while still having a complete record of the interview for analysis.

3.5.1.2 Phase 2: Structured interviews

The second phase of data collection in the research design comprised structured interviews, a quantitative research method (Winwood 2019). Compared to semi-structured and unstructured interviews, structured interviews allowed the interviewer to physically meet interviewees and to ask them the same set of pre-determined questions (Fox 2006; Saunders, Lewis & Thornhill 2019). In the current study, the purpose of conducting the structured interviews was to partially accomplish Objective 3 (OBJ.3), which was to develop an information processing model for QA in RLSCs of DW. To develop this model, the cause-and-effect relationships needed to be identified between: (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and the performance measurement criterion (i.e., QA); and (iii) IPMs and epistemic uncertainties. Quantitative data were needed to achieve this and could be obtained through pair-wise comparisons between variables (Jayasinghe, Rameezdeen & Chileshe 2022; Luu et al. 2009; Nadkarni & Shenoy 2004; Nasir, McCabe & Hartono 2003). Even if unstructured and semi-structured interviews enabled an in-depth overview of the selected research area (Winwood 2019), pair-wise relationships (Jayasinghe 2019) could not be derived from qualitative data obtained via these types of interviews; thus, they were disregarded for this phase.

Even if data collected from questionnaire surveys were quantifiable, the inherent advantages of structured interviews over questionnaire surveys helped the researcher to smoothly derive cause-and-effect relationships between variables in this study. Saunders, Lewis and Thornhill (2019) stated that structured interviews, in contrast to questionnaire surveys, provide an opportunity for the interviewer to explain in detail the aim of the study, the purpose of the interview and any ambiguous areas in the guideline. The interviewee also has the chance to query any information on which he/she needs further elaboration during the interview process. Bryman (2006) mentioned that, unlike questionnaire surveys, as interviewees are selected purposively in structured interviews, the researcher knows the interviewee before he/she participates in the interview. Therefore, compared to questionnaire surveys, structured interviews can be used to obtain rich and accurate responses from interviewees as the method provides an opportunity to select a true purposive sample, comprising experts with sound experience and knowledge in the field. In this phase of the current research, cause-and-effect relationships needed to be developed between epistemic uncertainties and IPMs, with

these identified through semi-structured interviews. Many of these epistemic uncertainties and IPMs originated from OIPT; however, these theoretical terminologies could undeniably be unfamiliar to industry practitioners. Even if definitions of these terminologies were provided with guidelines, the interviewees would expect more clarification when responding. Moreover, in line with the purpose of the current study, inexperienced or incompetent interviewees from the construction industry would not be able to make accurate pair-wise comparisons between the variables. Instead, the researcher sought to incorporate a purposive selection of interviewees with sound experience and expertise, holding decision-making positions and representing the construction industry's DW management sector. Given these requirements, the preference for structured interviews over a questionnaire survey was justifiable.

Many previous studies have used structured interviews when making pair-wise comparisons to develop cause-and-effect relationships between variables (Aldowah et al. 2020; Jayasinghe, Rameezdeen & Chileshe 2022; Luu et al.2009; Nasir, McCabe & Hartono 2003). All these studies used the cause-and-effect matrix for this purpose, as shown in Figure 3.3. In a typical cause-and-effect matrix as presented in Figure 3.3, the left column represents variables as causes, and the top row represents the variables as effects. During the data collection, the interviewees are required to rank each box in the matrix considering the nature of the relationships between each overlapping cause and effect variable based on specified criteria: 0 = no relationship, 1 = weak relationship, 2 = strong relationship, and 3 = very strong relationship (see Jayasinghe, Rameezdeen & Chileshe 2022; Nasir, McCabe & Hartono 2003). The boxes in the matrix where the same cause and effect variables overlap are shaded, indicating that those do not require any rank. For instance, the recent study by Jayasinghe, Rameezdeen and Chileshe (2022) used a cause-and-effect matrix comprising 20 risk factors affecting quality-related operational performance in RLSCs, obtaining 400 pair-wise comparisons between them through conducting structured interviews. Aldowah et al. (2020) derived 132 pair-wise comparisons between 12 factors responsible for the drop-out rate of massive open online courses in universities via structured interviews. It was observed from these previous studies that if the 'X' number of variables was available, the number of relationships derived from the pair-wise comparisons equals X^{X}-X. Therefore, it was not feasible in the current study to use a self-completed questionnaire as it would include many questions that a respondent would not be happy to answer

(Saunders, Lewis & Thornhill 2019). Consequently, it was decided that structured interviews, including a cause-and-effect matrix, were the most suitable data collection method to make pair-wise comparisons between variables to establish relationships; thus, they were adopted in this phase.

Effect / Cause	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6	Variable 7
Variable 1							
Variable 2							
Variable 3							
Variable 4							
Variable 5							
Variable 6							
Variable 7							

Figure 3.3. Cause-and-effect matrix for pair-wise comparisons

Purposive sampling, a non-probability sampling method, was used to recruit interviewees. In the *SAGE Dictionary of Social Research Methods,* Oliver (2006) defined the concept and objective of the purposive sampling method as follows:

> A form of non-probability sampling in which decisions concerning the individuals to be included in the sample are taken by the researcher, based upon a variety of criteria which may include specialist knowledge of the research issue, or capacity and willingness to participate in the research. Some types of research design necessitate researchers taking a decision about the individual participants who would be most likely to contribute appropriate data, both in terms of relevance and depth. (p. 2)

Although the purposive sampling method is always criticised as findings through this method cannot be generalised (Omair 2014), it can be used in quantitative studies, depending on their purpose (Apostolopoulos & Liargovas 2016; Onwuegbuzie & Collins 2007; Tongco 2007). Apostolopoulos and Liargovas (2016) mentioned that the purposive sampling method could be used in a quantitative study if it 'imposes the need to elicit the standpoints of experts on an issue where experts' knowledge is necessary'. Therefore, for the purposive sampling method to be used in a quantitative study, a pre-determined target group is needed, depending on the purpose of the research. In this study, to fulfil the purpose of the current phase, expert knowledge was a prerequisite for developing the cause-and-effect relationships between variables (Jayasinghe et al.

2022). Krueger et al. (2012) defined an expert as ‘anyone with relevant and extensive or in-depth experience in relation to a topic of interest’ (p. 4). Accordingly, the pre-determined group for structured interviews in this phase comprised interviewees with a minimum of 10 years of experience in the DW management sector. Furthermore, all interviewees held decision-making positions in their respective organisations. The initial contact with interviewees was first made through LinkedIn and websites of professional associations, such as the Waste Management Association of Australia and the Master Builders Association. An introductory email including comprehensive details of the purpose and objectives of the study was then sent to each of them in advance. Finally, the interview process was arranged for interviewees who expressed their interest in participating and agreed to take part.

Accordingly, 20 structured interviews were conducted with experts in the DW management sector, representing the building dismantling and on-site processing phase and the off-site waste processing phase across SA. The literature on purposive sampling reflects that sample size depends on the purpose of the research (Apostolopoulos & Liargovas 2016). Previous studies that made pair-wise comparisons to develop cause-and-effect relationships used various sample sizes of experts based on the purposive sampling method (Aldowah et al. 2020; Apostolopoulos & Liargovas 2016; Jayasinghe, Rameezdeen & Chileshe 2022; Nasir, McCabe & Hartono 2003). For instance, Aldowah et al. (2020) interviewed 17 experienced instructors to assess cause-and-effect relationships between factors affecting student drop-out in open online courses. Apostolopoulos and Liargovas (2016) interviewed 15 experts in the renewable energy area to make pair-wise comparisons between regional factors and the investment attractiveness of solar energy production. Furthermore, Nasir, McCabe and Hartono (2003) interviewed nine experts to derive cause-and-effect relationships to develop a schedule risk model for the construction industry. Luu et al. (2019) also interviewed nine experts to develop a risk management model for the construction industry. Notably, the latest study by Jayasinghe, Rameezdeen and Chileshe (2022) interviewed 18 experts to develop a BBN-based risk model for RLSCs of DW. According to these studies, a sample of not more than 20 experts was adequate for a study that aimed to make pair-wise comparisons to develop cause-and-effect relationships between variables, with this being the purpose of this phase of the current study. Consequently, the current study was on the safe ground regarding its sample size.

According to Bennett (1991), the standardised set of questions in structured interviews is determined in advance, based on the theoretical principles, perceived ideas or prior investigations. Correspondingly, the structured interview guideline in the current phase was prepared by incorporating epistemic uncertainties, with IPMs identified through semi-structured interviews in the first phase of data collection. The interview guideline included two cause-and-effect matrices (see Appendix 2[C]). The first matrix was to develop cause-and-effect relationships between the epistemic uncertainties that lead to IPNs. Thus, all 16 epistemic uncertainties revealed in the semi-structured interviews appear as causes and effects on either side (i.e., horizontal and vertical axes) of the table in the appendix (see Appendix 2[C]). In addition, this matrix was used to assess the effect of each epistemic uncertainty on the performance measurement criterion, that is, QA in RLSCs of DW. Interviewees were asked to rank the relationships based on the criteria: 0 = no relationship; 1 = weak relationship; 2 = strong relationship; and 3 = very strong relationship (see Jayasinghe, Rameezdeen & Chileshe 2022; Nasir, McCabe & Hartono 2003). The second matrix was used to develop cause-and-effect relationships between IPMs and epistemic uncertainties. Therefore, in this matrix, the 15 IPMs appeared as 'causes' on the vertical axis, and the 16 epistemic uncertainties appeared as 'effects' on the horizontal axis. Interviewees were asked to rank the relationships between IPMs and epistemic uncertainties based on the same criterion as in the first matrix, and considering the effectiveness of each IPM in responding successfully to the corresponding epistemic uncertainty. The boxes in the matrix where the same variables intersect were indicated as shaded boxes as these did not require a relationship. All interviews were conducted using a face-to-face approach and lasted for approximately 60–90 minutes. No probing questions were raised, but if the interviewee needed further clarification or support in understanding the question, the researcher responded to him/her during the interview.

After the structured interviews, the gathered data were analysed using the 'nine logical tests' introduced by Nasir, McCabe and Hartono (2003) to develop a causal map of information processing for QA in RLSCs of DW (see Subsection 3.5.2.2.1). This causal map was then transformed into a BBN-based conceptual information processing model for QA in RLSCs of DW using the principles of the causal mapping approach during the same data collection phase. This transformation process is described in detail in Subsection 3.5.2.2.2.

3.5.1.3 Phase 3: Focus group discussion

After the development of the BBN-based conceptual information processing model, the structure needed to be validated, with the study also needing to ensure that all relevant variables and relationships had been incorporated into the model (Jayasinghe 2019; Kleemann, Celio & Fürst 2017; Qazi et al. 2018). Hence, the third data collection phase empirically validated the BBN-based conceptual information processing model for QA developed in the previous data collection phase. To achieve this, a focus group discussion was organised and conducted.

Focus group discussions originated within the broad paradigm of qualitative research (Nyumba et al. 2018). The popularity and applications of focus group discussions have expanded across various disciplinary areas to compile ideas and perceptions about a particular topic from a homogenous group of experts within a minimal period (Sim & Waterfield 2019). A focus group discussion allows the researcher to listen, pay attention and moderate the brainstorming session, thus enabling valuable data to be unveiled on experiential narratives and appropriate statements in support of the face validity and content validity of a research framework or model (Chalabi, Mohamed & Mukhtar 2021; Connell et al. 2018; Engel et al. 2020; Kleemann, Celio & Fürst 2017). The term 'face validity' means the extent to which the developed instrument (i.e., either a model or a framework) is appropriate, sensible or relevant to the domain of interest (Holden 2010). Content validity refers to whether the instrument's content adequately represents the domain of interest (Polit & Beck 2004). With this understanding, previous studies have used focus group discussions to validate research frameworks (Subiyakto et al. 2015; Tapia, Daneva & van Eck 2007) and models (Chalabi, Mohamed & Mukhtar 2021; Jayasinghe 2019; Kleemann, Celio & Fürst 2017; Qazi et al. 2018) in terms of their structure, content and context. Notably, it was found that many studies used focus group discussions to validate BBN-based models (Jayasinghe 2019; Kleemann, Celio & Fürst 2017; Qazi et al. 2018), with this also being the purpose in the current study. In these previous studies, a focus group discussion was used as it facilitated the receiving of prompt constructive feedback on the instrument (Gundumogula 2020). Moreover, it was an easy-to-conduct technique that allowed the collection of data concurrently from a group of extremely busy experts who were not easily reachable (Martakis & Daneva 2013), with this also the case in the current study. Therefore, considering all these points, the current study chose to conduct a focus group discussion to empirically

validate the BBN-based conceptual information processing model for QA in RLSCs of DW.

Purposive sampling, a non-probability sampling method, was used to select participants for the focus group discussion. As explained in Subsection 3.5.1.2, the researcher's judgment is used in the purposive sampling method to recruit participants for a study. In a focus group discussion,

> participants are selected because they are [a] purposive, although not necessarily representative, sampling of a specific population, this group being 'focused' on a given topic. (Barbour & Schostak 2005, p. 46)

As the opinion of experts was sought in this phase, it was a prerequisite to select participants for the focus group discussion purposively, not simply to represent the population, but rather to select them based on their experience and expertise in the area of RLSCs of DW. Accordingly, a homogenous group of 11 experts involved in the DW management sector in SA were first invited for the study; however, only five attended the session. Of the five participants, three represented the off-site waste processing phase, while the remaining two represented the building dismantling and on-site processing phase. Notably, one participant currently engaged in the off-site waste processing phase also had previous experience in building dismantling and on-site processing. These participants had more than 10 years of experience in the domain and held senior designations in their respective organisations. Previous studies have suggested various limits to the number of participants that could be incorporated into a focus group discussion. For instance, Winke (2017) suggested that a group of five to 10 participants is more appropriate for a focus group discussion, while Daniel and Harland (2017) emphasised that a group of three to eight participants is adequate. However, depending on the setting, topic and objectives of the study, the size of the focus group can vary (Hasan 2019). Accordingly, previous studies aimed at empirically validating BBN-based conceptual models have used focus groups with the following sample sizes: five (Jayasinghe 2019); two (Qazi et al. 2018); and 11 (Kleemann, Celio & Fürst 2017). As found in previous studies, a group with less than four participants will fail to espouse the group dynamism needed for a focus group discussion (Saunders, Lewis & Thornhill 2019). In comparison, if more than 12 participants are involved, this will lead to the momentum of successfully conducting the session being lost due to the difficulty of managing the group. Consequently, the number of focus group participants

incorporated in the current study, that is, five participants, was within the acceptable range of sample sizes that previous studies asserted as sufficient for a focus group discussion.

A focus group discussion demands an exhaustive planning process to be a success. When reviewing the previous studies, it was found, in most cases, that the same procedure was followed regardless of the varying sequence of steps involved (see Stewart, Shamdasani & Rook 2007; Vaughn, Schumm & Sinagub 1996). Accordingly, the focus group discussion process of the current study was guided by previous studies. Qazi et al. (2018) highlighted that, to empirically validate a BBN-based conceptual model, the focus group needs to involve participants from the previous phase in which the model was developed and some new experts from the industry. On this note, six experts with the highest level of work experience and who were involved in the previous phase of structured interviews were initially contacted, by sending them an introductory email with the participant information sheet (see Appendix 3[B]) and consent form (see Appendix 3[A]). In all, five experts responded, but only three agreed to participate in the session. Five other experts engaged in the DW management sector and who were not involved in the previous data collection phase were then contacted through LinkedIn. Only three confirmed their interest in the focus group discussion. In total, six participants initially agreed to participate in the study. All potential participants were contacted two weeks before the session, and the focus group guide (see Appendix 3[C]) was sent to all agreed participants one week before the session to allow enough time for them to become familiar with the exercise. However, two days before the focus group discussion, one participant withdrew due to another commitment, leaving five participants for the study.

The focus group discussion was conducted in a venue easily accessible to all participants. As the focus group discussion was conducted during the pandemic, all guidelines related to preventing the spread of COVID-19, as outlined by SA Health, were followed during the discussion session. At the beginning of the discussion, a brief description of the research topic, its aim and the purpose of the study was given to participants. All participants were then invited to introduce themselves, a strategy that helped to build rapport and group cohesion (Liamputtong 2011). The consent forms were then distributed among participants for their signature. Each participant in the focus group discussion was provided with the status quo representation of the

information processing model developed after the structured interviews. The researcher explained the process that was followed to develop the model and guided the discussion with the instructions. Notably, the researcher played the moderator role in the focus group discussion as she was well aware of the study's purpose and process (Morgan & Krueger 1993; Winke 2017). The focus group discussion guide constituted open-ended questions and, where necessary, the researcher asked probing questions for further clarification. Previous studies highlighted that, depending on the purpose of the study, the structure of the focus group discussion could be highly structured with participants having a precise turn in which to answer the question or could be flexible with participants revealing their opinions at their will (Marvasti 2010). In the current study, the structure was flexible, with participants having enough freedom to express their opinions when they chose without following any pre-determined order. The moderator (i.e., the researcher) allowed each participant to actively engage in the discussion by stating their views, opinions and counterarguments. The discussion took nearly 90 minutes which is acceptable, as the common duration of a focus group discussion ranges from one to three hours (Liamputtong 2011). The focus group discussion was concluded by providing a summary to all participants and answering any questions asked by participants at the end of the discussion.

3.5.1.4 Phase 4: Case studies

The fourth data collection phase comprised case studies which were employed to assess the applicability of the information processing model for QA within real-world reverse supply chain contexts. Yin (2014) posited that:

> A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. (p. 18)

Parallel to this view, Yin (2018) stated that case studies are appropriate when a thorough examination of a particular issue is required. Yin (2009) mentioned that:

> Case studies have a distinctive place in evaluation research; the most important is to explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies. (p.19)

All these statements revealed that a case study is an appropriate research method for explaining causal links in a contemporary phenomenon that needs an in-depth investigation. In BBN-based modelling, even after cause-and-effect relationships have

been identified to develop the model which was then empirically validated, this would not be sufficient for holistic knowledge creation unless applied in a real-life scenario (Jayasinghe 2019; Qazi et al. 2018). Accordingly, previous studies have used case studies as an appropriate method to assess the applicability of the BBN-based models in different contexts. For instance, Luu et al. (2009) used two case studies to apply a BBN-based model to understand project delays in construction projects. Badurdeen et al. (2014), Garvey, Carnovale and Yeniyurt (2015) and Qazi et al. (2018) followed a single-case method to apply BBN-based risk models within supply chains. Babaleye, Kurt and Khan (2019) and Feng, Jiang and Wang (2020) carried out a single case study to apply their corresponding BBN-based models developed for the safety analysis of oil and gas wells and pipelines. Correspondingly, in the current study, the empirically validated BBN-based conceptual information processing model was applied in two cases to test its applicability and to observe how it supported decision making related to information processing for QA in RLSCs of DW.

For a case study, cases should be selected considering the unit of analysis and the number of cases selected for the study (Yin 2017). Based on these two criteria, Yin (2017) identified four different classifications of case study designs. Accordingly, as shown in Figure 3.4, a case study could be designed as single-case holistic, single-case embedded, multiple-case holistic and multiple-case embedded. The word ‘holistic’ refers to studies based on a single unit of analysis: if the study has several units of analysis, it is referred to as ‘embedded’.

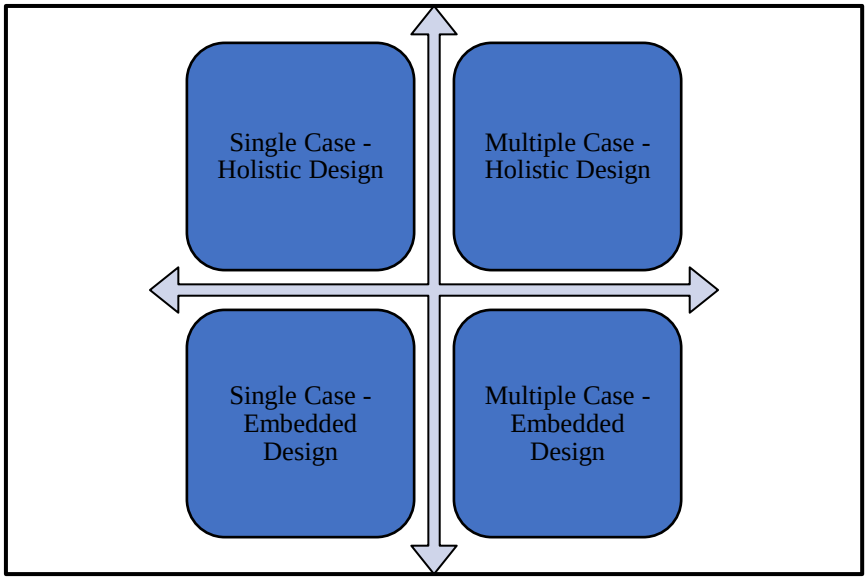


Figure 3.4. Case study designs

(Source: Adapted from Yin 2017)

The unit of analysis of this research was ‘an RLSC of DW’. As explained in Chapter 1, Section 1.5, an RLSC of DW is in a dyadic configuration, comprising two organisations representing the building dismantling and on-site phase and the off-site waste processing phase. As the current study was based on a single unit of analysis, that is, ‘an RLSC of DW’, it encompassed a holistic case study design. According to Merriam (1998), compared to a single-case design, a multiple-case design could reveal complementary aspects of a phenomenon while enhancing the external validity and robustness of the research findings. In a study with more than one case, the researcher could also understand the similarities and differences between the cases by analysing the data within and across the cases (Yin 2017). According to Saunders, Lewis and Thornhill (2019), a single-case design could only be used in critical, unique, common, revelatory and longitudinal contexts with strong justifications, with this not the case in RLSCs of DW in SA. Therefore, considering all these points, the multiple-case holistic design was used in the current study to fulfil Objective 4 (OBJ.4).

The number of cases in a case study should be determined based on theoretical sampling but not on statistical sampling (Eisenhardt 1989). With a similar argument, Tellis (1997) stated that a case study is not a sampling research method; instead, the decision on the number of cases should be based on maximising what can be understood within the available time for the study. Yin (2018) pointed out that the number of cases in a multiple-case design should be decided based on how much literal and theoretical replication is expected to be achieved through the study. Literal replication refers to auguring similar results, while theoretical replication refers to auguring contrasting results for known conditions. Considering the purposes for undertaking case studies and what had been done in previous similar studies, two cases were selected for this study (Case A and Case B). These two cases were RLSCs in a dyadic configuration involving two organisations representing the building dismantling and on-site processing phase and the off-site processing phase. Sangwan and Choudhary (2018) found that large-scale organisations performed better than small and medium-scale organisations in adopting green management practices such as RL. Generally, large-scale organisations differ from small and medium-scale organisations depending on their organisational structure, managerial styles and how they respond to their environment (Dasanayaka et al. 2022; Man, Lau & Chan 2002). For instance, previous studies revealed that the QM approaches of large-scale organisations were more specialised, standardised and

formalised in contrast to those of small and medium-scale organisations (Bishop 2018; North, Blackburn & Curran 1998). When considering the findings of the semi-structured interviews and the focus group discussion on the earlier data collection phases, many industry experts pointed out that the epistemic uncertainties for QA and the ways of responding to them differed from large-scale organisations to small and medium-scale organisations. Given these points, two dissimilar RLSCs were selected as case studies: one with a large-scale demolisher and waste processor and the other with a small and medium-scale demolisher and waste processor, indicating the current study's expectation of theoretical replication.

3.5.1.4.1 Case study process

As mentioned above, two RLSCs involved in DW management were selected for the case studies in this phase. In each of these RLSCs, two organisations were involved, one representing the building dismantling and on-site processing phase, the other representing the off-site waste processing phase. The procedure followed by Kanyoma, Agbola and Oloruntoba (2021) to form a supply chain for a case study was used in the current study. In the first step, as focal organisations of RLSCs, two waste processors, that is, a large-scale waste processor and a small and medium-scale waste processor, were contacted. The choice for the supply chains, each with a large and small and medium-scale waste processor, was made with the expectation of providing contrasting findings and ensuring the theoretical replicability of the study (see Eisenhardt & Graebner 2007). According to Gilfillan (2018), in the Australian context, the organisation's size is determined based on the number of people employed and the annual revenue turnover. Consequently, as per the Australian Bureau of Statistics and the Australian Taxation Office (as cited in Gilfillan 2018), an organisation that employs a maximum of 199 employees with an annual turnover of not more than A$250 million is considered a small and medium-scale organisation. Moreover, if the organisation employs 200 or more employees with an annual turnover of more than A$250 million, it is considered a large-scale organisation. In the second step, the waste processors contacted were asked to identify the corresponding key input customers (i.e., demolishers) in their supply chains that brought them the highest amount of waste for reprocessing in 2019–2020. Finally, these identified demolishers (key customers) were invited to participate in creating the two dyad supply chains for the study.

As observed by Saunders, Lewis and Thornhill (2019), a case study often uses either a single data collection method or a combination of methods: archival records and documentation, different means of observation, interviews and focus group discussions, questionnaires, and research diaries and other research aids. Direct or participant observation was not suited for the current phase of data collection as its purpose was probabilistic inference (i.e., deriving probabilities of variables in the model) using conditional probability tables (CPTs) with direct involvement of experts. Furthermore, archival records, documentation, research diaries and other research aids were also not appropriate as information related to epistemic uncertainties for QA did not exist in the industry as explicit knowledge but as implicit knowledge which needed to be obtained from experts in the industry. Zhang (2017) stated that it is more appropriate to conduct probability elicitation in one-to-one sessions, either collectively or individually; thus, questionnaires were not suited for this data collection phase. On this note, CPTs could be completed either from focus group discussions with experts' consensus or from individual sessions, such as interviews, to derive one set of CPTs from each expert. The current study adopted the former option as it was the method commonly used for probabilistic inference in previous studies (Jayasinghe 2019; Librantz et al. 2021; Qazi et al. 2018), enabling group interactions and stimulating discussions on the topic among participants (Saunders, Lewis & Thornhill 2019). Therefore, to complete CPTs through eliciting probabilities, four experts were incorporated into the focus group discussion in Case I (which comprised large-scale organisations) and three in Case II (which comprised small and medium-scale organisations). Two participants in Case I were from the demolishing organisation of the supply chain, while the remaining two were from the waste processing organisation. In Case II, two participants represented the waste processing organisation in the supply chain, while only one was from the demolishing organisation. According to Librantz et al. (2021), no minimum number of experts is stipulated for incorporation into decision-making processes, as in the case of probability elicitation. Generally, the number of experts could vary from three to 20 depending on the level of experience and knowledge that they possess of the area under study (Dey 2010; Sharma & Kumar 2015). Previous studies which used focus group discussions for probabilistic inference of BBN-based models have incorporated different numbers of participants: five (Jayasinghe 2019), two (Qazi et al. 2018) and four (Librantz et al. 2020). In the current study, all the experts involved in the focus group discussions had more than 15 years of experience in DW management, as well as

sound knowledge of the area and the fundamentals of probability theory, as they all held senior decision-making roles in their respective organisations. For instance, even though only three participants were involved in Case II, two were Managing Directors and had more than 25 years of experience. For these reasons, the number of experts assigned to the focus group discussions in this phase was considered adequate. During the focus group discussions, participants were provided with the guideline in Appendix 4(C) which includes CPTs for each variable in the BBN-based model of the current study. The experts were instructed to complete these CPTs collaboratively with probabilities using the given probability scale (see Appendix 4[C]). The reason for using a probability scale was that not all the experts were comfortable expressing their beliefs in probabilistic form without having a guide (Knochenhauer et al. 2013). A detailed explanation of the CPTs and their probabilistic inferences were provided in Subsection 3.5.2.3.3. The focus group discussions in this phase took approximately two hours, an acceptable period for a focus group discussion (Liamputtong 2011).

The next subsection presents a comprehensive discussion of the selected data analysis methods that followed data collection in all four phases of the research design.

3.5.2 Data analysis

After collecting data, data analysis methods provide closely related options for obtaining answers to the research questions. Accordingly, this subsection discusses the data analysis methods used for analysing the qualitative and quantitative data collected from the data collection methods discussed in Subsection 3.5.1.

3.5.2.1 Qualitative data analysis

In this study, qualitative data analysis was conducted for the data collected from the following data collection methods:

Phase 1: Semi-structured interviews
Phase 3: Focus group discussions

Content analysis, a widely used data analysis technique in qualitative research (Kyngäs 2020), was followed to analyse the data collected from the above two phases in the current research. According to Hsieh and Shannon (2005), qualitative content analysis is:

> A research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or pattern. (p. 1278)

Qualitative content analysis rests on the assumption that texts are a rich data source that could reveal valuable and meaningful descriptions (Johnson, Adkins & Chauvin 2020) 'to provide knowledge and understanding of the phenomenon under study' (Downe-Wamboldt, 1992, p. 314). Text data could be in verbal, print or electronic form and could be obtained from narrative responses, open-ended surveys, interviews, focus groups, observations and documents such as articles, books or manuals (Kondracki, Wellman & Amundson 2002). The output of the qualitative content analysis may result in the form of codes, themes or patterns (Elo & Kyngäs 2008; Zhang & Wildemuth 2009).

Previous studies identified three distinct approaches for qualitative content analysis: conventional (inductive), directed (deductive) and summative (Hsieh & Shannon 2005; Mayring 2014). Table 3.2 outlines the differences between these three approaches. In conventional content analysis (inductive), the most popular qualitative data analysis approach, the researcher does not use a priori codes as existing theory or literature is limited; thus, all the codes are derived from the data during analysis (Hsieh & Shannon 2005; Johnson, Adkins & Chauvin 2020). This approach therefore advocates the development of theories or conceptual frameworks (Vaismoradi et al. 2016; Vaismoradi, Turunen & Bondas 2013) which should be further refined, developed, tested or validated by using directed (deductive) content analysis (Elo & Kyngäs 2008). In directed (deductive) content analysis, the researcher attempts to describe a phenomenon already described by an existing theory and prior research (Hsieh & Shannon 2005; Johnson, Adkins & Chauvin 2020). In this approach, most codes are defined before the data analysis from the existing theory or prior research. However, new codes could also be defined from data during the analysis (Lodi, Smit & Ayirebi 2004). A descriptive approach is undertaken in summative content analysis to identify and quantify the particular words or context in the text to provide insight into the contextual use of words or content in the research area (Hsieh & Shannon 2005; Johnson, Adkins & Chauvin 2020). Of all three approaches to qualitative content analysis, the current study used the 'directed content analysis' for data analysis in both qualitative data collection phases (Phases 1 and 3). The justifications for the choice and

the steps followed in the directed content analysis are discussed in the following subsection.

Table 3.2. Differences between three approaches to qualitative content analysis

Type of content analysis	Conventional (inductive) content analysis	Directed (deductive) content analysis	Summative content analysis
When to use	When little is known about the phenomenon under study as existing theory or literature is limited	To extend or validate an extant theory or prior research or to understand how a theory or prior research applies to an issue under investigation	To understand the contextual use of particular words or content
Study starts with	Observation	Theory	Keywords
Sources of codes	Data	Theory or prior research	Interest of the researcher or review of the literature
When to define codes/ keywords	During the data analysis	Before and during the data analysis	Before and during the data analysis

(Source: Adapted from Hsieh & Shannon 2005; Lodi, Smit & Ayirebi 2004)

3.5.2.1.1 Directed content analysis

In this study, directed content analysis was used to analyse qualitative data collected from the semi-structured interviews (Phase 1) and the focus group discussion (Phase 3). As explained in Subsection 3.5.1.1, the purpose of conducting the semi-structured interviews was to firstly establish how process, people, policy and technology contribute to QA (Objective 1 [OB.1]). The current study aimed to empirically validate the findings of the study on 'Quality assurance in reverse logistics supply chains of demolition waste: A systematic literature review' by Wijewickrama et al. (2021a). Therefore, when analysing the qualitative data to fulfil Objective 1, most codes were deductively derived from the study by Wijewickrama et al. (2021a). Secondly, semi-structured interviews also fulfilled Objective 2 by identifying the epistemic uncertainties that lead to IPNs and corresponding IPMs for QA in RLSCs of DW. A holistic understanding of information processing under epistemic uncertainties is presented by the seminal study by Galbraith (1973, 1974) which encompassed OIPT's introduction. This theory and prior research explained information processing under epistemic uncertainty but not in the context of RLSCs of DW. Therefore, when analysing the qualitative data to fulfil Objective 2, most codes were deductively derived

from the OIPT-related extant literature. Furthermore, as explained in Subsection 3.5.1.3, a focus group discussion was conducted to empirically validate the BBN-based conceptual information processing model for QA, developed via structured interviews. As the qualitative data in this phase were related to refining, developing and validating the constructs identified in the previous data collection phase to develop the BBN-based model, analysing them using directed content analysis was admissible. In all the above cases, in addition to the a priori codes, whenever possible, new codes were defined from data during the analysis.

Previous studies have suggested varying methods for directed content analysis (see Elo & Kyngäs 2008; Hsieh & Shannon 2005; Mayring 2014; Zhang & Wildemuth 2009). Consolidating all these methods, Assarroudi et al. (2018) elaborated a three-phased method of directed content analysis, comprising 'preparation', 'organisation' and 'reporting', as discussed in the following paragraphs.

Preparation phase for directed content analysis

As explained in Subsections 3.5.1.1 and 3.5.1.3, the purposive sampling method was used to recruit interviewees and participants for the semi-structured interviews and focus group discussion, respectively. Accordingly, 30 semi-structured interviews were conducted with practitioners external and internal to RLSCs of DW: at the point of 30 interviews, it was perceived that no additional data would be revealed in subsequent interviews. Five experts from the DW management industry participated in the focus group discussion, with this number within the acceptable range for a focus group discussion, as explained in Subsection 3.5.1.3. Before starting data collection, it was decided that only the manifested content, that is, the transcribed interview text (Elo & Kyngäs 2008), would be considered for the analyses of qualitative data collected from semi-structured interviews and the focus group discussion. With that in mind, the interview and focus group guides (see Appendices 1[C] and 3[C]), including open-ended questions, were developed before each data collection phase (Hsieh & Shannon 2005). In addition, the researcher was free to ask probing questions when clarifications were needed on particular issues. After each semi-structured interview and focus group discussion, the entire interview/discussion was immediately transcribed verbatim. After preparing the transcripts, they were again checked with the original audio-recording to ensure accuracy. Before moving to the organisation phase, the transcriptions were iteratively read and reviewed to familiarise the researcher with the data and, thus, to

comprehend the broader meaning of interviewees' excerpts (Elo & Kyngäs 2008). While reading, whenever a new idea or issue emerged from the data, relevant notes were taken as it was thought that it could add an interesting finding to the study.

Organisation phase for directed content analysis

The researcher used QSR NVivo 12 to analyse the study's qualitative data. The researcher first created the study's preliminary open codes. These open codes were then consolidated into similar groups and formed axial codes. In the fourth step, the axial codes were refined, reviewed and grouped to create selective codes which were the study's final themes. The word 'code' refers to a basic information element extracted from the data from which a meaningful statement on the phenomenon under study is derived (Saldaña 2016). While codes in directed content analysis could be derived from an extant theory, prior research or collected data (Hsieh & Shannon 2005; Lodi, Smit & Airebi 2004), in the current study, they were derived from all three of these sources. For instance, when analysing the semi-structured interviews, the initial open codes to fulfil Objective 2 were derived from OIPT and associated prior research associated, especially research on epistemic uncertainties and IPMs. However, it was also observed that some pieces of evidence did not seem to fit the theory, as they were exclusively related to RLSCs of DW. For example, some IPMs, such as 'waste acceptance criteria/gate fees', could not be explained with concepts presented in the OIPT-related literature. The final coding structure of semi-structured interview data therefore included codes that not only originated from theory and prior research but also from the data, thus being aligned with the directed content analysis concept. The final coding structure of the focus group discussion included codes related to the validation of the constructs and relationships in the existing BBN-based model. The model was developed via structured interviews, with a few relationships omitted from, and others added to, the BBN-based model. As the last step, the study's selective codes or final themes were reviewed and refined by cross-checking with the collected raw data. This iterative process helped to identify new themes and avoided duplication in the derived themes (Braun & Clarke 2006).

Reporting phase for directed content analysis

In the last phase, a detailed description of the data analysis process, as in this chapter and in the research findings, was systematically presented (see Chapters 4 and 6). The study's findings were presented with broad categories of themes, including appropriate

excerpts. Finally, the criteria adopted to enhance the trustworthiness of the qualitative studies were also outlined (see Subsection 3.5.2.1.2).

3.5.2.1.2 Trustworthiness of qualitative data

In qualitative research, trustworthiness means the degree of confidence (rigour) in the data, interpretations and methods used to ensure the quality of the study (Polit & Beck 2010). As in all scientific inquiry, qualitative research should fulfil four criteria to ensure the study's trustworthiness: truth value, consistency, neutrality and applicability (Guba 1981; McGinley et al. 2021). Firstly, the term 'truth value' means 'confidence in the truth of the findings' (Guba 1981, p. 79) which could establish the study's credibility (Lincoln & Guba 1985). The current study incorporated interviewees and focus group participants with more than eight years of experience who held senior and decision-making positions in RLSCs of DW to establish the truth value. All these interviewees/participants expressed their willingness and interest in participating in the study. Member checking further enhances the credibility of a qualitative study (Chileshe, Rameezdeen & Hosseini 2016). Thus, the transcriptions were sent back to interviewees to verify their excerpts; however, not all interviewees responded. Both consistency and neutrality were achieved through data triangulation and an audit trail. The word 'consistency' refers to the idea that the same findings would be generated if the study was repeated with the same procedure (McGinley et al. 2021). Guba (1981) further explained that the word 'neutrality' refers to the degree to which findings are free from researchers' bias, motivations, interests and perspectives. Both these criteria can be ensured through an audit trail that helps an external auditor to understand the transparency of the research path (Korstjens & Moser 2018). The current study achieved an audit trail by providing a complete description of decisions made during the research process and sampling, and the research materials utilised. Furthermore, data triangulation showed that the interview findings were consistent with the literature review findings; thus, the findings are shown to be free from the researcher's bias. Finally, the word 'applicability' refers to the degree to which the findings could apply in other contexts (Guba 1981) or to how the study's findings could be generalised. Often, generalisability is not mentioned in qualitative research other than as a limitation or weakness of the study (Smith 2018). Unlike quantitative studies, readers need to undertake much work to evaluate how the results apply to new situations in qualitative studies (Maxwell 2021). Even if statistical generalisation is not possible for qualitative

research, Smith (2018) asserted that the following four types of generalisations could be made from qualitative research: one or more combinations of naturalistic, transferability, analytical and intersectional generalisability. For naturalistic generalisation, this study presented illustrative quotes from interviewees and focus group participants (see Chapters 4 and 6), enabling readers to resonate interviewees' and participants' experiences with their own personal experiences. Furthermore, a thick description was made, enabling transferability of the research setting, study participants and observed processes. Due to this, readers could make a good judgment call by applying all or part of the findings in a different setting.

3.5.2.2 Quantitative data analysis: Cause-and-effect relationships

This subsection discusses the quantitative analysis of data collected from the structured interviews in Phase 2 of data collection. The two headings of the discussion are (1) development of a causal map and (2) transformation of the causal map into a Bayesian belief network (BBN)-based model.

3.5.2.2.1 Development of a causal map

This subsection explains the process followed in developing a causal map of information processing for QA in RLSCs of DW. As discussed in Subsection 3.5.1.2, completed cause-and-effect matrices were collected from 20 interviewees. In these cause-and-effect matrices, interviewees scored each relationship between two variables as 0, 1, 2 or 3. The quantitative analysis adopted a procedure comprising nine logical tests introduced by Nasir, McCabe and Hartono (2003) to obtain conditional dependence relationships between variables. Previous studies that developed BBN-based models also applied the same tests to compute cause-and-effect relationships between the different variables (Jayasinghe, Rameezdeen & Chileshe 2022; Luu et al. 2009). Figure 3.5 shows the criteria included in these nine logical tests. As shown in Figure 3.5, these tests used two statistical values: average and skewness. The word 'skewness' describes 'the weight of the opinion' (Nasir, McCabe & Hartono 2003, p. 523). A positive skewness value emphasises that most experts gave a low score, but a few gave a higher score and vice versa. Additionally, the notation 'weak (W)' indicated the number of experts who scored the relationship as either 0 or 1, while the notation 'strong (S)' indicated the number of experts scoring the relationship as 2 or 3.

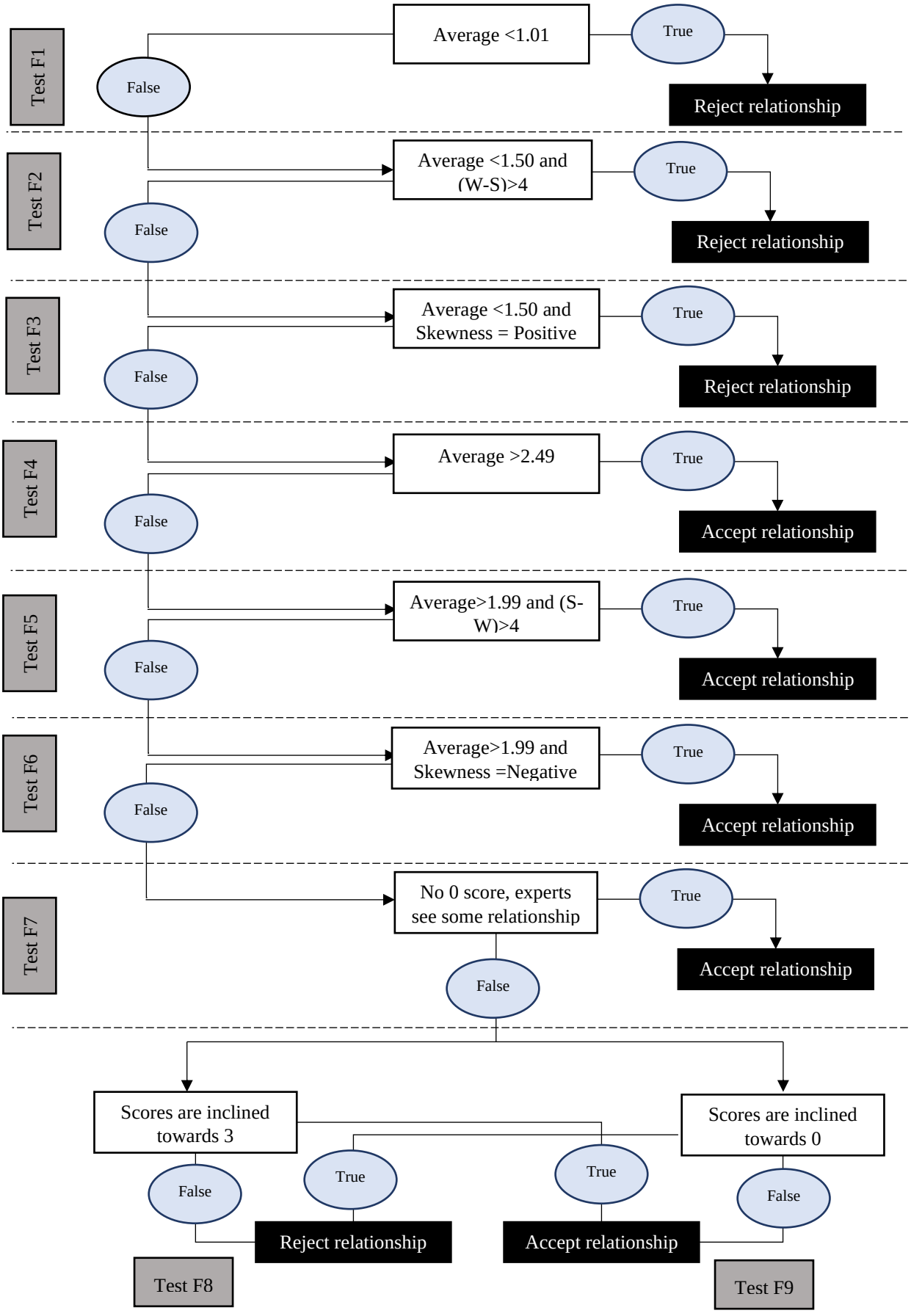


Figure 3.5. Nine logical tests

(Source: Adapted from Nasir, McCabe & Hartono 2003)

The difference between these two values, that is, 'W' and 'S', indicated the measure of the weight of the experts' opinions. As Figure 3.5 shows, Tests F1 to F3 were the 'Rejection tests', and Tests F4 to F6 were the 'Acceptance tests'. Tests F7, F8 and F9 were called observation tests, as in those tests, the decision to accept or reject depended on observing the experts' scores. For instance, if most scores were inclined towards 3, those relationships were accepted in Test F8, while if most were inclined towards 0, those relationships were rejected in Test F9. After this analysis, only the accepted relationships were considered for developing the preliminary causal map (see Chapter 5, Section 5.6). The next subsection explains the process through which the preliminary causal map was transformed into a BBN-based model.

3.5.2.2.2 Transformation of the causal map into a BBN-based model

Causal maps represent cause-and-effect relationships in the form of nodes and arrows (Nadkarni & Shenoy 2004). According to these authors, a causal map is also known as a cause map or cognitive map. Eden, Ackermann and Cropper (1992) defined a causal map as a directed graph 'characterised by a hierarchical structure which is most often in the form of a means/ends graph' (p. 310). These causal maps explain that the interactions between certain variables lead to a particular outcome. An example of a causal map is presented in Figure 3.6.

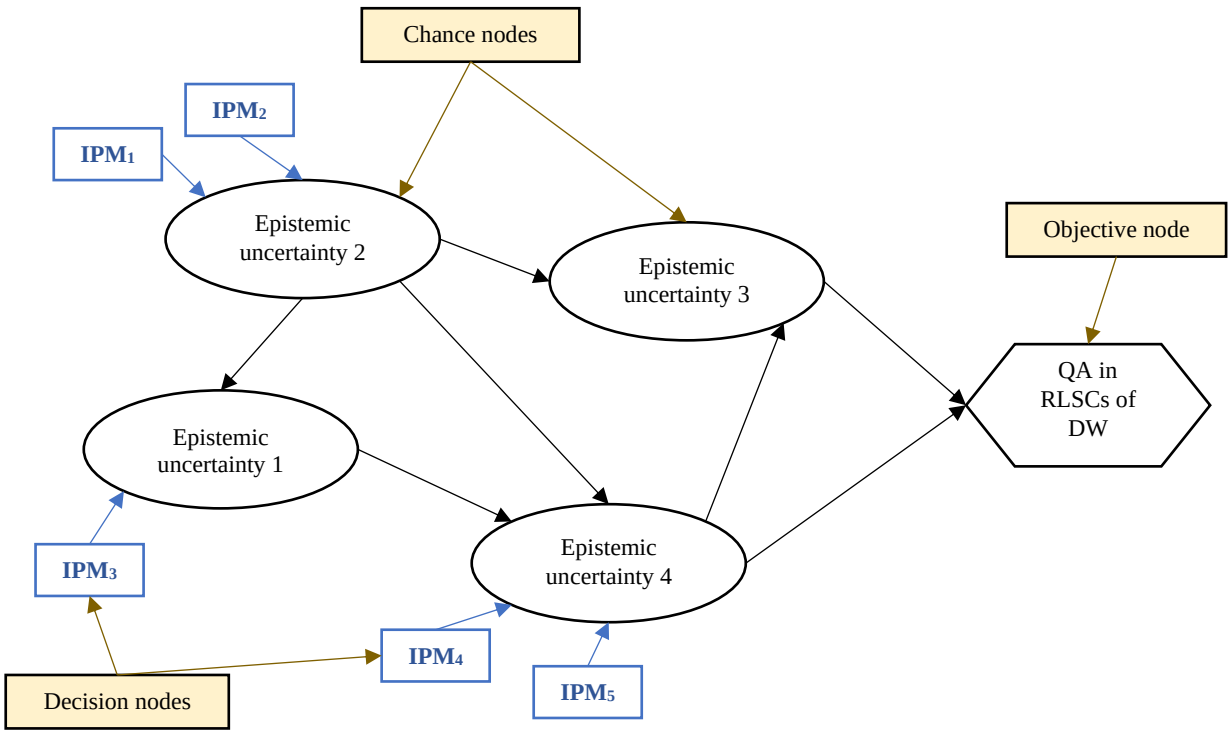


Figure 3.6. Example of a causal map

A causal map encompasses three major components: causal concept, causal connection and causal value. Firstly, the causal concept, represented by a node in the causal map, is an ideational category that can be an attribute, issue, factor or variable in the area under study (Giabbanelli et al. 2022). As shown in Figure 3.6, two main types of nodes are found in a causal map: decision nodes and chance nodes (Qazi et al. 2018). The decision node is a controllable variable that decision-makers can modify directly, while the chance nodes represent variables that cannot be controlled directly. Accordingly, the epistemic uncertainties which could not be controlled directly were represented through chance nodes in the current study. As decision-makers in RLSCs could control the IPMs in response to epistemic uncertainties, the IPMs were represented by decision nodes in the current study, as shown in Figure 3.6. The systematic effect of these nodes in the current study that led to QA in RLSCs of DW was represented through an objective node (Giabbanelli et al. 2022). Crawford et al.'s (2020) previous study also used 'process quality' as the objective node of the causal map developed for QC in the resin transfer moulding process. Secondly, the causal connection represented by a unidirectional arrow is the link between the two causal concepts on the map (Jayasinghe 2019). The concept at the arrow's tail is deemed the 'cause' while the concept at the head is the 'effect'. When considering only the cause-and-effect relationships between chance nodes, the node at the arrow's tail is the child node, and the node at the arrow's head is the parent node. A causal connection could be either positive or negative (Nadkarni & Shenoy 2004). A positive connection shows that an increase in the cause concept leads to an increment in the effect concept. In contrast, in a negative connection, the increment in the cause concept leads to a decrease in the effect concept and vice versa. Accordingly, in the current study, positive causal connections appeared between epistemic uncertainties, while negative connections were found between IPMs and epistemic uncertainties. Thirdly, the causal value indicates 'the strength of the causal connection' (Nadkarni & Shenoy 2004, p. 263). As the causal map in the current study was developed to construct a BBN-based model, causal values were obtained through Bayesian probabilities, as in the study by Qazi et al. (2018) (see Subsection 3.5.2.3).

Causal maps differ from the BBN-based models in several aspects, even though both have cause-and-effect relationships (Giabbanelli et al. 2022). Therefore, when transforming the causal map into a BBN-based model, those differences should be

addressed in the causal map. Table 3.3 summarises the differences between a causal map and a BBN-based model, with these discussed in detail in the following paragraphs.

Table 3.3. Differences between a causal map and a BBN-based model

	Differences		Transformation of a causal map into a BBN-based model
	Causal map	**BBN-based model**	
1.	Circular relationships or causal loops exist	Circular relationships or causal loops cannot exist.	Eliminating circular relationships
2.	Both direct and indirect relationships are included	Direct relationships are redundant when an indirect relationship is found between two concepts given a third mediating concept. However, exemptions exist.	Distinguishing between direct and indirect relationships
3.	Causal relationships adhere to both deductive and abductive reasoning.	Causal relationships adhere only to deductive reasoning.	Reasoning underlying cause-and-effect relationships
4.	Act as a dependence map (D-map)	Incorporate partial characteristics of both the D-map and the independence map (I-map)	Conditional independencies

1 Eliminating circular relationships

The circular relationships in causal maps do not comply with the acyclic graphical structure needed for a BBN-based model (Nadkarni & Shenoy 2004). Therefore, it is crucial to eliminate circular relationships to transform causal maps into BBN-based models. The reasons for the exitance of circular loops are twofold (Eden, Ackermann & Cropper 1992; Jayasinghe 2019). First, unwanted and inappropriate relationships could exist that need to be eliminated. Second, concepts could represent dynamic relations across different time frames. As the current study's BBN-based model did not consider the time factor, circular relationships were not eliminated, justifying different time frames. Therefore, in this study, inappropriate circular relationships were eliminated, as shown in Figure 3.7 (indicated in red), by distinguishing causal linkages between concepts based on deductive versus abductive reasoning, which is explained under '3. Reasoning underlying cause-and-effect relationships'.

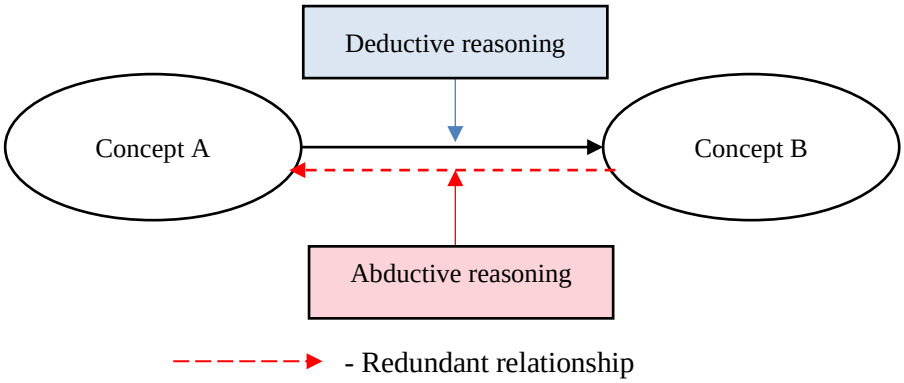


Figure 3.7. Eliminating circular relationships

2 Distinguishing between direct and indirect relationships

Direct and indirect relationships between concepts are not considered when developing causal maps (Eden, Ackermann & Cropper 1992; Eden, Jones & Sims 1979). For instance, a direct link between two concepts in a causal map does not always guarantee a direct relationship. Instead, it could be either direct or indirect. The rationale brought by principles of the causal mapping approach here is that when completing the cause-and-effect matrices, the respondents put higher ratings for some relationships between variables as they are significantly related (Jayasinghe 2019; Nadkarni & Shenoy 2004). However, in reality, those variables have a significant relationship not as they are directly related but due to an indirect relationship between them due to the presence of another variable(s). The distinction between these two types of relationships is important when transforming a causal map into a BBN-based model.

The three reasons for distinguishing between direct and indirect cause-and-effect relationships (Nadkarni & Shenoy 2004) are as follows. Firstly, it advocates for accurately understanding the nature of the relationships between concepts. For instance, Figure 3.8(a) explains that the effect of Concept A on Concept C is completely modelled by the effect of the first Concept A on a third mediating Concept B which, in turn, is a cause of the second Concept C. Consequently, the direct relationship between Concepts A and C is redundant; thus, it can be disregarded in the BBN-based model. Secondly, it helps to avoid redundant relationships in the model, increasing the complexity of representation and probability elicitation. Thirdly, the distinction between direct and indirect relationships is needed to identify the conditional independencies crucial for inferences in a BBN-based models. However, all direct relationships between concepts that have indirect relationships via mediating concepts are not redundant and should not be eliminated if the real picture of the context is described (Jayasinghe

2019). Therefore, after eliminating all redundant relationships, the cited author raised the need for empirical validation of the BBN-based model before applying it in the industry, the same process followed in the current study.

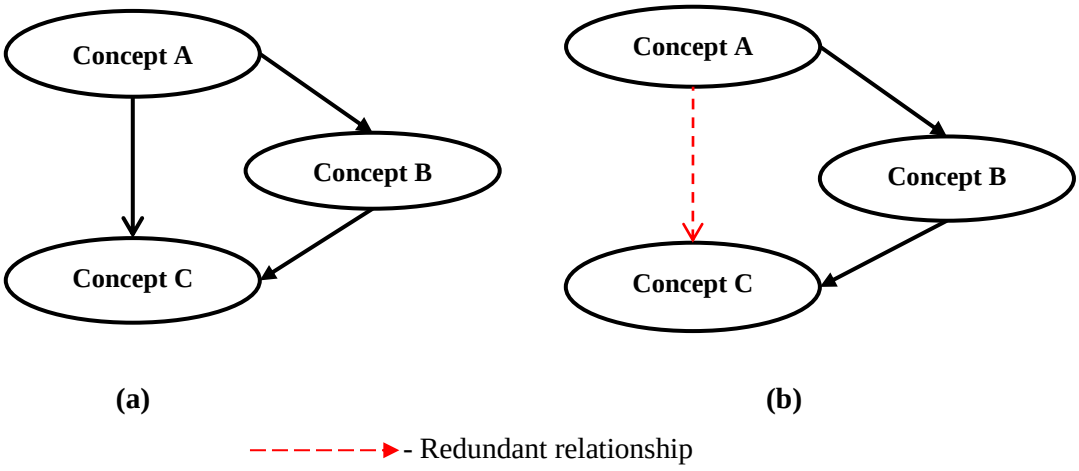


Figure 3.8. Distinguishing between direct and indirect relationships

3 Reasoning underlying cause-and-effect relationships

The development of causal maps completely relies on individuals' perceptions of the cause-and-effect relationships between concepts rather than on absolute reasoning processes (Jayasinghe 2019; Nadkarni & Shenoy 2004). According to these previous studies, individuals observe cause-and-effect relationships between concepts with two types of reasoning lenses: deductive and abductive. In deductive reasoning, individuals reason in the direction of causation, that is, from causes to effects. In contrast, in the abductive reasoning process, individuals reason in the opposite direction to causation, that is, from effects to causes. Nadkarni and Shenoy (2004) stated that causal relationships derived from abductive reasoning should be eliminated from a causal map when transforming it into a BBN-based model as they expressed a misrepresentation through creating a causal connection from effect to cause. Additionally, these causal connections sometimes create circular relationships in causal maps that need to be eliminated, based on deductive/abductive reasoning, as explained above. Therefore, during the process of transforming the causal map into a BBN-based model in the current study, all relationships that rely upon abductive reasoning were eliminated, leaving only those relationships that follow deductive reasoning.

4 Conditional independencies

The causal map is a dependence map (D-map) in which the causal connections indicate that the connected concepts are related. However, in a D-map, the absence of an arrow does not indicate independence between the two concepts (Nadkarni & Shenoy 2004). The reason is that the process of developing causal maps is mostly exploratory, with causal connections determined based on experts' elicitations (Nadkarni & Shenoy 2004). For instance, in the current study, the causal map was developed from the cause-and-effect matrices completed by 20 experts in the DW management industry. When completing the matrices, these experts did not indicate which nodes were independent. On the other hand, in an independence map (I-map), the absence of a causal connector between two concepts indicates that they are independent, whereas the presence of a causal connector does not indicate that the two concepts are related.

On the one hand, a BBN-based model is an I-map, in which the separated concepts are conditionally independent, given the other variables (Nadkarni & Shenoy 2004). On the other hand, a BBN-based model is a D-map as the presence of causal connections between concepts implies that they are dependent. Therefore, to transform into a BBN-based model, the causal map must embrace partial functions of both D-maps and I-maps (Nadkarni & Shenoy 2004). These authors further highlighted that this transformation step could be accomplished via empirical validation of the developed model, which the current study undertook through a focus group discussion (see Subsection 3.5.1.3).

3.5.2.3 Quantitative data analysis: Bayesian belief network (BBN) modelling

Many studies have identified the development of BBNs as a formal modelling technique for representing epistemic uncertainties (Khanmohammadi 2021; Leong 2018). The BBNs are multivariate statistical models acknowledged as a unique probabilistic approach using subjective and objective data (Qazi et al. 2018). The BBNs are developed based on two structural model components: (i) a directed acyclic graph (DAG) that indicates the dependencies and independencies between the variables and (ii) conditional probability tables (CPTs) indicating the strengths of the relationships in the graph (Panidhapu et al. 2020). The DAG outlines the modelled system of variables in which the directional arrows represent the cause-and-effect relationships between the variables. The strengths of these cause-and-effect relationships between variables in the DAG are quantified through conditional probabilities derived through CPTs.

The BBNs have been widely used in various scientific domains in construction supply chains, especially in the areas of risk analysis (Guan et al. 2020; Jayasinghe 2019), delay analysis (Balta, Dikmen & Birgonul 2021; Wang, P et al. 2022) and health and safety analysis (Guo et al. 2020) due to their intrinsic characteristics which have advantages over the other modelling techniques. Table 3.4 outlines a few modelling techniques, including BBNs and their inherent capabilities.

Table 3.4. Comparison between different modelling techniques

	FMEA/ FMECA	**FT**	**AHP**	**SD**	**PN**	**BBN**
Representation of logical relationships	No	Logical	Logical	Physical	Physical	Logical
Capturing interdependencies	No	Yes (deterministic)	Yes (deterministic)	Yes (deterministic)	Yes (deterministic)	Yes (non-deterministic)
Ability to visual modelling	No	Yes	Yes	Yes	Yes	Yes

FMEA/ FMECA - Failure modes and effects analysis/ failure mode and effect criticality analysis; FT – Fault tree; AHP – Analytic hierarchy process; SD - System dynamics; BBN - Bayesian belief network

(Source: Adapted from Jayasinghe 2019)

Leerojanaprapa (2014) asserted that some modelling techniques, such as failure modes and effects analysis (FMEA) or failure mode and effects criticality analysis (FMECA), are unable to represent logical or physical relationships between variables in a visual model. Thus, these techniques are not ideal for the context of the current study. Compared with the BBN, Petri nets (PNs), another modelling technique, do not support detailed propagation analysis of the variables under consideration (Garvey, Carnovale & Yeniyurt 2015). The BBNs facilitate forward propagation and back-propagation to distinguish the root causes of the variables in a model (Sakib et al. 2021). Many modelling techniques facilitate capturing interdependencies between variables (Jayasinghe 2019). The two types of dependencies are deterministic and non-deterministic. As shown in Table 3.4, most analysis techniques hold a deterministic dependency, meaning that the output is known (Leerojanaprapa 2014). In contrast, the BBN has a non-deterministic dependency; thus, the output cannot be revealed in

advance (Ashrafi, Davoudpour & Khodakarami 2015). According to Henriksen et al. (2017), the BBNs can form cause-and-effect relationships between variables in complicated settings through non-deterministic dependence. This advantage of the BBN technique has led it to be used over the other techniques for modelling variables under consideration in complicated supply chains, such as RLSCs of DW (Jayasinghe 2019; Langseth & Portinale 2007). Given the above points, it is evident that, compared with other modelling techniques, the BBNs are more effective in visualising causal relationships between variables in complex settings, thus enabling their propagation analysis. Therefore, BBN analysis is the most appropriate technique for the current study to develop the information processing model for QA in RLSCs of DW.

Despite criticism over the representation of epistemic uncertainties using probabilities, Goldstein (2006) mentioned that the BBN approach helps to 'quantify your uncertainties as probabilities' (p. 403). According to Leong (2018), epistemic uncertainties could be due to two situations: (i) the uncertain situation is known, but the information is unknown (i.e., known uncertainties) or (ii) both situation and information are unknown (i.e., unknown uncertainties). Simply stated, in known epistemic uncertainties, the probability of the occurrence of an event involving unknown information (deficient information event) is known, but not in unknown epistemic uncertainties. Importantly, previous studies asserted that BBN-enabled probability analysis is appropriate to quantify different possible outcomes of known epistemic uncertainties (Bullen, Fahey & Kenway 2006; Khanmohammadi 2021; York & Venkataraman 2010). As clarified by Khanmohammadi (2021), the probability of known epistemic uncertainties could be expressed in subjective knowledge-based probabilities. It is a recurrent point in the body of literature that RLSCs of DW are deficient in information (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b). Internal stakeholders in RLSCs of DW are indeed aware of the situations in which they lack information. Hence, the BBN analysis technique with subjective knowledge-based probabilities was used in the current study to ascertain the known epistemic uncertainties for QA in RLSCs of DW. The following subsections present an introduction to Bayes' theorem and a detailed description of the BBN modelling approach undertaken in the current study.

3.5.2.3.1 Bayes' theorem

Bayesian networks are directed acyclic graphs that advocate the development of relationships between variables represented by nodes and links (Librantz et al. 2021). The mathematical background of Bayesian networks relies on Bayes' theorem (Feng, Jiang & Wang 2020). According to Hosseini and Sarder (2019), Bayes' theorem can change the prior probability of an unknown variable upon the occurrence of another variable related to the initial one. Bayesian networks are used widely to help solve decision-making problems using recorded or prior knowledge about the issue under investigation and its resultant effects (Jayasinghe, Rameezdeen & Chileshe 2022). This theory completely relies on the notions of 'conditional probability' and 'conditional independence' between the variables of the model (Lemmer & Kanal 2014); thus, they have been formally defined as follows:

Suppose two events are called event A and event B. Regarding the probability of occurrence of these two events, based on Bayes' theory, the conditional probability of event A for a given event B could be expressed mathematically as in Eq. 1:

$$P(A/B) = \frac{P(B/A).P(A)}{P(B)} \qquad \text{(Eq. 1)}$$

where *P(A/B)* is the 'posterior probability', which is the conditional probability of event A given the observation of evidence of event B; *P(A)* is the 'prior probability' of event A; and *P(B/A)* is the likelihood of the occurrence of event B when event A has occurred.

In Bayes' theory, conditional independence describes situations in which events A and B are conditionally independent, giving the third event, event C. As a result, when the value of event C is known, the revised belief of event A provides no information on event B, with this shown in Eq. 2:

$$P(B/A,C) = P(B/C) \qquad \text{(Eq. 2)}$$

A key strength of a BBN is that it facilitates propagation; the probability distributions could therefore be updated in response to changes in the entry of evidence. The chain rule for BBNs, derived as follows, is used to calculate these updated probabilities.

The conditional probability equation in Eq. 1 can be rearranged to give the product rule as follows:

$$P(A \cap B) = P(B/A)\, P(A) \qquad \text{(Eq. 3)}$$

Expanding the above equation for three variables gives the following equation:

$$P(A \cap B \cap C) = P(A/B \cap C)\, P(B \cap C)$$
$$= P(A/B \cap C)\, P(B/C)\, P(C) \qquad \text{(Eq. 4)}$$

Generalising the above equation for the 'n' number of variables provides the joint probability distribution *P(X)* as follows:

$$P(X_1 \cap X_2 \cap X_3 \cap \ldots . X_n)$$
$$= P(X_1/X_2 \cap \ldots \cap X_n)\, P(X_2/X_3 \cap \ldots X_n) \ldots P(X_{n-1}/X_n)\, P(X_n)$$

$$P(X) = \prod_{i=1}^{n} P(X_i/pa(X_i))$$

(Eq. 5)

where $pa(X_i)$ are the parents of Xi.

The development process of a BBN consists of two steps: qualitative and quantitative (Balta, Dikmen & Birgonul 2021; Jayasinghe 2019). The graphical representation of dependencies between the variables was developed in the first step (i.e., the qualitative step) in this research, also known as 'structural learning'. A causal map was developed and then transformed into a BBN-based model (see Subsections 3.5.1.2 and 3.5.2.2). This BBN-based model consisted of a set of variables in the form of nodes and a set of directed arcs or links denoting the causal relationships between these nodes. Most BBN-based models, especially those that are large and complicated, have root nodes (i.e., any node without parents) and leaf nodes (i.e., any node without children). In this research, Chapters 5 and 6 explain the structural learning process of the BBN-based conceptual information processing model for QA in RLSCs of DW. The second step, that is, the quantitative step is known as 'parametric learning' which represents the quantification of cause-and-effect relationships between variables in the model. In this step, a probabilistic approach was used to determine the probability of occurrence of each variable (Balta, Dikmen & Birgonul 2021; Jayasinghe 2019). According to previous studies, either algorithms developed from historical data or experts' opinions were used to collect quantitative probabilistic information for parametric learning (Badurdeen et al. 2014; Librantz et al. 2020; Luu et al. 2009; Nasir, McCabe & Hartono 2003). The RLSCs in the construction industry are still being developed in SA (Jayasinghe 2019),

and QA in RLSCs has not been discussed hitherto in empirical research. Consequently, no historical data were found related to the epistemic uncertainties in DW management; thus, it was not feasible to develop algorithms in the current study. Therefore, experts' opinions or expert elicitations were used for the parametric learning step of the BBN-based model development in the current study.

It is difficult to manually calculate the current and adjusted probabilities of variables in a complicated BBN-based model (Leerojanaprapa 2014). Therefore, many software tools have been developed to make the parametric learning of a BBN model more convenient and practical, as listed by Korb and Nicholson (2011). Various studies have used GeNIe software (version 3.0) which was recommended by many previous studies as versatile and user friendly for BBN modelling (Leerojanaprapa 2014; Qazi et al. 2018; Zhang 2017). This software was developed at the Decision Systems Laboratory at the University of Pittsburgh and has been available for use since 1997 (Decision Systems Laboratory 2013). As this software was free for academic use, the current study was able to proceed with no hesitation in developing complicated models which was a major limitation if using trial versions of other commercial software.

3.5.2.3.2 Parametric learning process

At the beginning of the parametric learning process, each chance node in the model should be defined with particular probabilistic information (Balta, Dikmen & Birgonul 2021). The process of defining this probabilistic information consists of three stages, as explained in the following points.

1 Defining the status of chance nodes

Each chance node of the model should be given a status before introducing the model for probability elicitation. According to Nasir (2000), 'the conditions of the variable or node are called states' (p. 10). The probable states of a node should be mutually exclusive and exhaustive (Korb & Nicholson 2011). The mutual exclusiveness of states indicates that only one status could occur at a time. At the same time, the exhaustiveness of states means that the given states of a chance node should cover all possible events of its occurrence.

Each chance node in the BBN-based model should be defined using a set of a finite number of states (Rafiq, Chryssanthopoulos & Sathananthan 2015). As Nasir (2000)

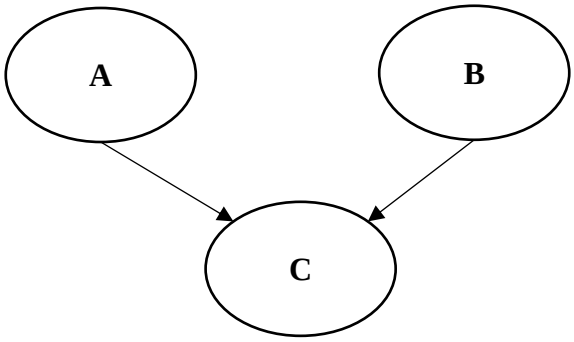
reported, ‘each of the nodes has two states: yes and no. A variable can have more than two states as well’ (p. 10). However, it is more effective if not too many states are defined for a particular node as that would make the probability elicitation tedious for experts (Pollino & Henderson 2010). Many of the previous studies have defined mostly two or a maximum of three states for nodes in a BBN-based model (Jayasinghe 2019; Librantz et al. 2020; Nasir 2000). Congruently, the chance nodes which represent epistemic uncertainties for QA in the BBN-based model in the current study were also assigned two states, ‘Yes’ and ‘No’. When developing the BBN-based model using the software (i.e., GeNIe [version 3.0] in the current study), the states of each chance node should be defined during the creating process. The summation of probabilities assigned to each of the states of a particular node should equal one (‘1’) (Nasir 2000).

2 Conditional probability tables (CPTs)

A conditional probability table (CPT) is formed based on the relationship between a child node and its parent nodes, as shown in Figure 3.9. Pollino and Henderson (2010) elucidated that a CPT describes ‘the probability of being within a state, given a combination of values of parent states’ (p. 10). The size of the CPT of a particular node is the product of the number of states of the child node and all its parent nodes (Pollino & Henderson 2010). For instance, if a node with two states has five parent nodes, the former node requires 2^5 or 32 probabilities for its CPT to be completed. If a node has no parent nodes (i.e., a root node), only the prior marginal probabilities of each status of the node are required to complete its CPT (Pollino & Henderson 2010). With the increase in the number of parent nodes, the number of probabilities that need to be elicited increases, making probability elicitation ineffective as it consumes a large amount of time and becomes a tedious activity for experts (Nasir 2000). However, in the current study, the maximum number of parent nodes for a child node was five which is a manageable number for probability elicitation, as revealed by Nasir (2000).

As shown in Figure 3.9, the child node and two-parent nodes are binomial, including states of ‘Yes’ and ‘No’. Since nodes A and B are root nodes, they could be defined only by their prior marginal probabilities. In contrast, the probabilities of each status of node C, the child node of nodes A and B, are conditional and vary with the different combinations of states of A and B.

A – Probability table	
Yes	0.2548
No	0.7452



B – Probability table	
Yes	0.4562
No	0.5438

C – Conditional probability table				
A	**Yes**		**No**	
B	**Yes**	**No**	**Yes**	**No**
Yes	0.9400	0.8400	0.2500	0.1100
No	0.0600	0.1600	0.7500	0.8900

Figure 3.9. Examples of conditional probability tables (CPTs)

3 Making probabilistic inferences

Probabilistic inferences are needed to compute the marginal probabilities of the variables in a BBN-based model (Nadkarni & Shenoy 2004). The term ‘marginal probability’ means the probability of occurrence of a particular variable at a specific state. In this study, the probability of the occurrence of an epistemic uncertainty derived through the calculation of probabilistic inferences was termed the ‘prior marginal probability’. The method of derivation of prior marginal probabilities differed depending whether it was a parent or child variable. If a root cause variable in the BBN-based model has no parent nodes, its prior marginal probability equals the input probability without any further calculations. For example, when considering the CPTs in Figure 3.9, the prior marginal probabilities of A, a parent node, are X = Yes: 0.2546 and X = No: 0.24578. Similarly, the prior marginal probabilities of B could also be easily distinguished as they are equal to the input probabilities. However, the prior marginal probability of C could not be derived directly; thus, it should be calculated as per Eq. 6:

$$P(C)_{Yes} = P\left(\frac{Y}{A,B}\right)P(A)P(B) + P\left(\frac{Y}{\backsim A,B}\right)P(\backsim A)P(B) + P\left(\frac{Y}{A,\backsim B}\right)P(A)P(\backsim B) + P\left(\frac{Y}{\backsim A,\backsim B}\right)P(\backsim A)P(\backsim B)$$

(Eq. 6)

$P(C)_{Yes} = (0.9400 * 0.2548 * 0.4562) + (0.8400 * 0.2548 * 0.5438) + (0.2500 * 0.7452 * 0.4562) + (0.1100 * 0.7452 * 0.5438)$

$P(C)_{Yes} = 0.1092 + 0.1164 + 0.0850 + 0.0446$

$P(C)_{Yes} = 0.3552$

$Therefore,\ P(C)_{No} = 0.6448$

The above example shows how to manually calculate the prior marginal probabilities of a node with two parent nodes. In the current study, the software (i.e., GeNIe [version 3.0]) calculated the prior marginal probabilities of all the child chance nodes in the BBN-based model; thus, manual calculation was unnecessary.

The performance measurement criteria (i.e., QA in RLSCs of DW) was denoted as an objective node in the BBN-based model in the current study, which was inferred through utility values. The word 'utility value' refers to 'relative satisfaction offered by a particular outcome' (Lee & Bradshaw 1998, p. 16). Accordingly, in the current study, relative satisfaction with QA in the RLSC was quantified through utility values, as in the study by Crawford et al. (2020). Qazi et al. (2018) noted that the utility values of a BBN are defined with the different states of the chance nodes that are directly linked with the objective node. Therefore, as with chance nodes, the experts elicited the utility values of QA in RLSCs of DW at each different state of the workflow uncertainties of the demolisher and waste processor using a separate scale, as shown in Appendix 4(C). The expected utility value of the decision-maker related to the BBN modelling was calculated using the following equation (see Qazi et al. 2018):

$$EU = \sum P(p^i_{1,}\, p^i_{2,} \dots\dots, p^i_0) * U(p^i_{1,}\, p^i_{2,} \dots\dots, p^i_0) \qquad \text{(Eq. 7)}$$

where $P\left(p^i_{2,} \dots\dots, p^i_0\right)$ represents the joint probability of chance nodes linked with the objective node realising in the specific combination of states and $U(p^i_{1,}\, p^i_{2,} \dots\dots, p^i_0)$ represents the utility values at each specific combination of states.

3.5.2.3.3 Computation of epistemic uncertainty propagation of the developed BBN-based model

After the computation of prior marginal probabilities of the chance nodes and the utility value of the performance measurement criterion, the BBN-based model was ready for the varying methods of analyses to provide a holistic understanding of the epistemic

uncertainty propagation of QA in a particular case allied to RLSCs of DW. For these different types of analyses, it was important to compute the posterior marginal probabilities, which was done easily through the software tool used in the study. The term ‘a posterior marginal probability’ refers to:

> The probability of each variable being in a particular state when the set of evidence variables have been observed by specifying observed states. (Leerojanaprapa 2014, p. 60)

In simple terms, posterior marginal probability means the adjusted probability of a variable after knowing the specific states of its evidence variable(s). Figure 3.10 presents the derivation process of posterior marginal probabilities from the prior probabilities elicited by the experts. According to Leerojanaprapa (2014), the posterior marginal probability can be calculated using Eq. 1 (in Subsection 3.5.2.3.1). In its general form, this equation is as follows:

$$P(A/B) = \frac{P(B/A).P(A)}{P(B)} \qquad \text{(Eq. 1)}$$

where *P(B)* is the prior probability of *B* which refers to the belief about *B* before observing any evidence; *P(A)* represents the observed probability of *A*; *P(A/B)* is the conditional probability of *A* if the variable *B* has occurred; and *P(B/A)* is the posterior marginal probability of *B* given *A*.

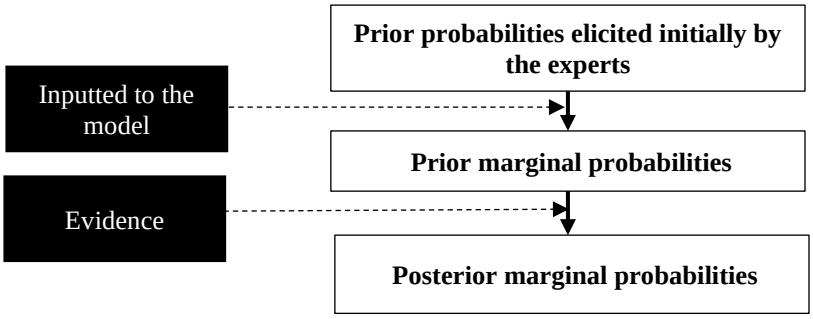


Figure 3.10. Derivation process for posterior marginal probabilities from elicited probabilities

(Source: Adapted from Jayasinghe 2019)

When the BBN-based model is more complicated, including more variables and arrows, the manual calculation of posterior marginal probabilities becomes more complex and difficult (Jayasinghe 2019). This is the main reason for using a software tool like GeNIe (version 3.0) to support the analysis, which easily enables the derivation of the posterior marginal probability of any variable, given the evidence of associated variables either

through forward propagation or back-propagation (Jayasinghe 2019; Nadkarni & Shenoy 2004). In this study, the prior and posterior marginal probability values were used and compared against each other for different analyses, as explained in Table 3.5. These analyses were first done within each case of the two selected case studies. Subsequently, a cross-case analysis was done to distinguish within-group similarities and intergroup differences (Eisenhardt 1989) to provide a holistic understanding of information processing for QA in RLSCs of DW (see Chapter 7).

Table 3.5. Different types of quantitative analyses based on the developed BBN-based model

No.	Type of analysis	How has it been done?	Why has it been done?
1	Sensitivity analysis (see Chapter 7, Subsections 7.3.1.1 and 7.4.1.1)	The change in the utility value of QA in RLSCs of DW was considered by changing the states of the input cause variables (i.e., 16 epistemic uncertainties) in the BBN-based model.	To test the robustness of the model (Leerojanaprapa 2014; Qazi et al. 2018). To understand the epistemic uncertainties whose slight change could make a huge deviation in satisfaction with QA in RLSCs of DW. This analysis helped distinguish the most sensitive epistemic uncertainties of QA in RLSCs of DW.
2	Root cause analysis (see Chapter 7, Subsections 7.3.1.2 and 7.4.1.2)	The analysis was conducted using the back-propagation function enabled in BBN-based models (Badurdeen et al. 2014; Leerojanaprapa 2014). In general, back-propagation means studying the backward propagation of variables in the model from the output to the input variables (Jayasinghe 2019). This analysis distinguished the root cause epistemic uncertainties with the highest posterior marginal probabilities when workflow uncertainties of each of the demolisher and waste processor were 100% present (i.e., status=Yes).	To identify the critical path of epistemic uncertainties that augments the workflow uncertainties of both demolisher and waste processor.
3	Analysis of IPMs (see Chapter 7, Subsections 7.3.1.3 and 7.4.1.3)	The analysis was conducted by changing the status of decision nodes (i.e., No to Yes) to see how prior marginal probabilities of chance nodes and the utility value vary. In other terms, it found out how prior marginal probabilities of epistemic uncertainties and the utility value of QA fluctuate	To observe the effect of each and all IPMs on the prior marginal probabilities of epistemic uncertainties and the utility value of QA. By doing so, this analysis advocated distinguishing the significant IPMs for QA in RLSCs of DW.

No.	Type of analysis	How has it been done?	Why has it been done?
		depending on the joint and individual implementation of IPMs.	
4	Scenario analysis (see Subsections 7.3.1.4 and 7.4.1.4)	The analysis was conducted using the forward propagation function enabled in BBN-based models (Ashrafi, Davoudpour & Khodkarami 2015; Leerojanaprapa 2014). First, the observed and focused variables were decided. Next, depending on the different scenarios (i.e., Scenario A – status (Yes), Scenario B – status (No), Scenario C – after implementing IPMs) of each observed variable, the percentages of difference could be found in the posterior marginal probabilities/utility value of the focused variables were determined.	To check whether the model behaves appropriately, enabling forward propagation (Ashrafi, Davoudpour & Khodkarami 2015; Leerojanaprapa 2014). To observe the combined effect on a particular variable(s) (i.e., observed variables) due to changes in the states of several epistemic uncertainties under different classifications (i.e., focused variables). In other words, this analysis was done to identify the significance of macro-, meso- and micro-level uncertainties on QA in RLSCs of DW.

3.5.2.3.4 Model validation and verification

Model validation and verification are important steps in any model development process if the model needs to be accepted and used for decision-making purposes (Thacker et al. 2004). The following paragraphs discuss how the validation and verification were undertaken as they related to the BBN-based model of the current study.

Model validation

Model validation answers the question, 'does the model represent and correctly reproduce the behaviours of the real-world system?' (Woodward 2012, p. 79). Validation confirms that the model is useful, in other words, that it fulfils the anticipated requirements, addresses the issue under consideration and provides accurate information about the context being modelled. Woodward (2012) stated that the validation approaches rely on the model's type, purpose and intended use. Most previous studies related to BBN modelling have used 'face validity' as the technique for empirical validation of the models (see Jayasinghe 2019; Kleemann, Celio & Fürst 2017; Qazi et al. 2018). In face validity, the model is presented to experts in the subject area to confirm that the model and its elements are valid based on its face appearance (Eddy 2006). Accordingly, a focus group discussion was conducted in the current study to validate the BBN-based model qualitatively, as discussed in Subsection 3.5.1.3. The

experts who participated in the focus group discussion suggested a few additions and deductions to the BBN-based conceptual model as presented in line with the real-world context of RLSCs of DW (see Chapter 6). At the conclusion of the empirical validation, the model was ready to be used to derive probabilistic inferences (parametric learning process), as discussed in Subsection 3.5.2.3.2.

Model verification

According to Woodward (2012), model verification answers the question: 'does the model perform as intended?' (p. 79). Therefore, model verification confirms that the model development has followed the right process. The current study used the GeNie (version 3.0) software tool for model verification, with this mainly supporting quantitive verification methods (Cypko et al. 2017; Druzdzel 1999; Leerojanaprapa 2014). This software advocated checking for common modelling errors, such as ensuring that the variable states were mutually exclusive and exhaustive. Subsection 3.5.2.3.3 showed the quantitative data analysis techniques used under the parametric learning process, such as sensitivity analysis and scenario analysis, which helped to verify that the model performed as intended (see Kleemann, Celio & Fürst 2017).

3.6 Ethics Considerations

In social sciences research involving human interactions, it is paramount that ethics, in simple words, 'moral values', are considered (Brittain et al. 2020). According to the National Health and Medical Research Council (2007), adherence to the proper standards, language and procedures while conducting human-centric research protects the dignity, rights and welfare of research participants. In general, ethics considerations of social sciences research encompass obtaining participants' consent and ensuring their confidentiality and safety during their involvement (Trochim 2006). This research project was primarily based on experts' knowledge and opinions incorporated through semi-structured interviews, structured interviews, a focus group discussion and case studies. Therefore, ethics considerations were imperative when conducting the current research.

Accordingly, the University of South Australia's Human Research Ethics Committee granted ethics approval for the current project on 02/03/2020. When preparing all data collection guidelines in the current study, the essential ethical principles were of utmost consideration, such as trust, accountability, mutual respect and fairness (National Health

and Medical Research Council 2007). Before conducting any method of data collection, an information sheet (see Appendices 1[B], 2[B], 3[B] and 4[B]) describing the research aim and purpose of the particular data collection session was provided to the study's participants. Participants were asked to sign a consent form (see Appendices 1[A], 2[A], 3[A] and 4[A]) before any session to ensure the study adhered to the principle of 'informed consent of those taking part' (Hardicre 2014). Through the consent form, the researcher, using appropriate ethical language, informed participants that the session would only be conducted at their discretion, no external pressure would be placed on them, and that they had the right to withdraw at any time. The consent form further assured participants that their confidentiality, anonymity, data privacy and security would be assured. Participants were also informed through the consent form of the contact details if any ethical issues arose through their participation in the research. During data analysis and write-up, fictitious terms were used for the study's participants to maintain their confidentiality and anonymity. The researcher was fully accountable for reporting findings from the data collection as the primary data without making any modifications.

3.7 Concluding Remarks

This chapter discussed the research setting, approach and methods used in designing the current study. The study followed an exploratory mixed-methods approach, comprising four sequential data collection phases. In the first phase, semi-structured interviews were conducted to lay the initial groundwork of the study by establishing how process, people, policy and technology contribute to QA in RLSCs of DW and identifying the epistemic uncertainties that lead to IPNs and corresponding IPMs for QA in RLSCs of DW. In the second phase, structured interviews were conducted to determine the cause-and-effect relationships needed to develop the BBN-based conceptual information processing model for QA in RLSCs of DW. In the third phase, a focus group discussion was conducted to empirically validate the developed model. Finally, the model was applied in two case studies to assess the applicability of the BBN-based approach for analysing information processing for QA in the context of RLSCs of DW. Qualitative data were analysed using the directed content analysis technique, while the quantitative data were analysed using statistical tests and BBN analysis. Due to the human-centric nature of the research, all the data collection methods were planned, prepared and

conducted with utmost adherence to ethics considerations. The following chapters discuss the findings of each data collection method.

4 Information Processing for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

4.1 Introduction

This chapter presents the empirical findings of the semi-structured interviews which comprised the first data collection phase. The semi-structured interviews were conducted to obtain insights into information-centric QA in RLSCs of DW, thus helping to develop the questions for the subsequent structured interviews. Accordingly, this chapter first presents the profile of the interviewees, followed by the content analysis of the semi-structured interviews. This chapter establishes how process, people, policy and technology contribute to QA in RLSCs of DW. The chapter then discusses the epistemic uncertainties that lead to IPNs and IPMs for QA in RLSCs of DW. Finally, the findings are summarised as an information processing map for QA in RLSCs of DW.

4.2 Demographic Information of Interviewees: Semi-structured Interviews

Thirty (30) semi-structured interviews were conducted to establish aspects of the QAS in RLSCs and to identify the epistemic uncertainties (that lead to IPNs) and IPMs for quality assurance (QA). As discussed in Chapter 3, the semi-structured interviews were conducted with internal and external stakeholders of RLSCs of DW in South Australia (SA). Accordingly, 24 interviewees were internal stakeholders with a minimum of eight years of experience in CDW management, representing building dismantling and on-site processing and off-site waste processing sectors. Additionally, six interviewees were external stakeholders with a minimum of 10 years of experience, representing regulatory sectors that indirectly influence the South Australian DW management industry. These external stakeholders were attentive to the RLSC setting and its QA procedures. As external stakeholders were peripheral to the internal supply chain, they

were more eager than internal stakeholders to highlight the existing deficiencies of the supply chain. Incorporating internal and external stakeholders ensured adequacy in building up the context behind QA in RLSCs of DW. Table 4.1 outlines the profile of the interviewees. Subsequently, the interviewees will be named using the labels (codes) allocated in Table 4.1.

Table 4.1 Profile of interviewees (semi-structured interviews)

Sector of representation	Interviewee (Code)	Designation	Experience (years)
Building dismantling and on-site processing	BD1	Managing Director	19
	BD2	Managing Director	28
	BD3	Managing Director	21
	BD4	Quality Control and Sales Manager	18
	BD5	Sales and Marketing Manager	18
	BD6	Director	14
	BD7	Director	16
	BD8	Contracts Manager	19
	BD9	Managing Director	30
	BD10	Operations Manager	10
	BD11	Managing Director	23
	BD12	Contracts Manager	32
	BD13	Managing Director	22
Off-site waste processing	WP1	Strategic Business Development Manager	11
	WP2	Accounts Manager	16
	WP3	Human Resource and Occupational Health and Safety Manager	10
	WP4	Accounts Manager	08
	WP5	Regional Manager	08
	WP6	Sales and Marketing Manager	15
	WP7	General Manager	11
	WP8	Sales and Marketing Manager	10
	WP9	Accounts Manager	30
	WP10	Senior Sustainability Advisor	15
	WP11	Principal Sustainability Advisor	13
Regulatory sector (State government agencies)	SG1	Chief Executive	28
	SG2	Regulatory Manager	20
	SG3	Senior Environmental Advisor	22
	SG4	Regulatory Manager	11
Regulatory sector (Local government agencies)	LG1	General Manager	23
	LG2	Development Officer	24

As shown in Table 4.1, all interviewees had experience ranging from 8–32 years. The interviewees' average length of experience was 18 years; notably, 12 of the 30 interviewees had more than 20 years of experience. As shown in Table 4.1, all interviewees held senior positions in their organisations. The quality and validity of these findings were enhanced through the incorporation of interviewees with senior designations (Lin et al. 2019). All were well aware of the QA procedures of RLSCs,

their associated information deficiencies (i.e., epistemic uncertainties) and ways to minimise/avoid those deficiencies (i.e., IPMs). All interviewees showed their interest in participating in the study; thus, they expressed their ideas and opinions effortlessly, enhancing the data quality of the study (Simms & Rogers 2006). The same set of questions was used for all interviews regardless of the type of stakeholder category. The next section discusses the coding process use for data analysis of the semi-structured interviews.

4.3 Identification of Themes

Figure 4.1 illustrates the arrangement of the findings in Chapter 4. As shown, the chapter discusses the findings of the semi-structured interviews, the first data collection phase of this research. The semi-structured interview findings were first used to establish how process, people, policy and technology contribute to QA in RLSCs of DW (see Chapter 3, Subsection 3.5.1.1). The epistemic uncertainties leading to IPNs and IPMs for QA were then identified. Finally, all the findings were used to develop an information processing map for QA.

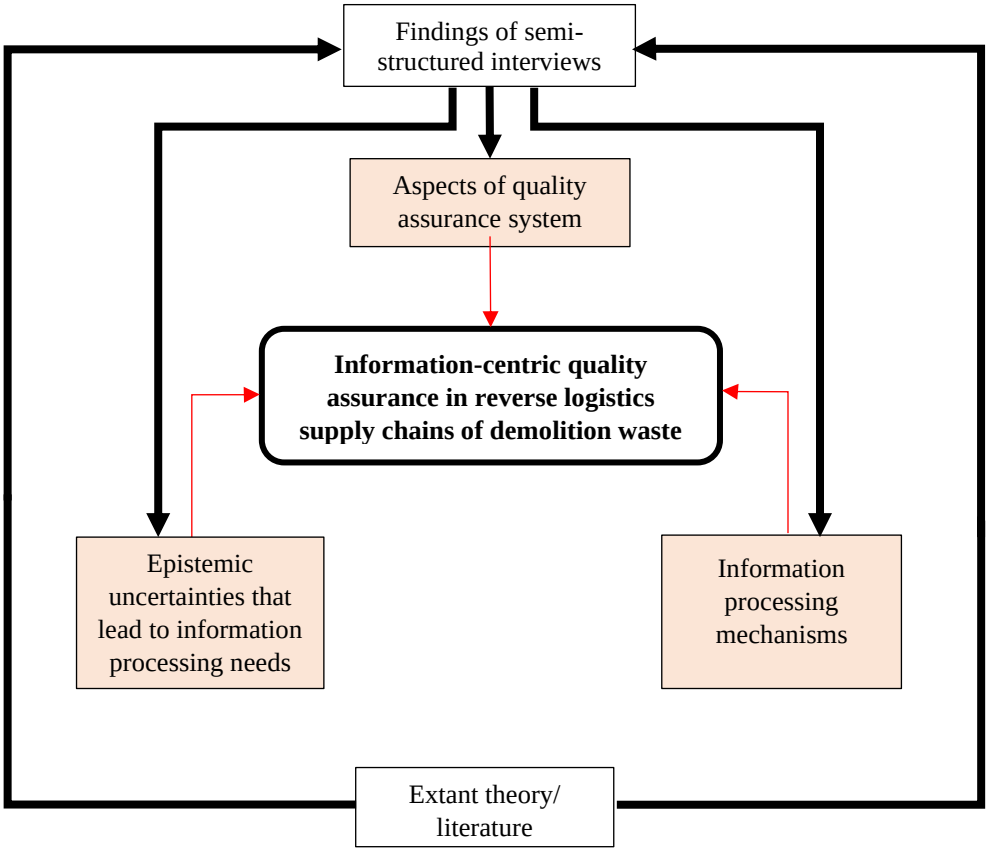


Figure 4.1. Arrangement of findings of semi-structured interviews

The qualitative data obtained from the semi-structured interviews were analysed following the directed content analysis method employing both deductive and inductive approaches (see Chapter 3, Subsection 3.5.2.1). The following subsections explain how the themes were identified for 'aspects of QAS' and 'epistemic uncertainties and IPMs for QA in RLSCs of DW'.

4.3.1 Themes' identification for 'aspects of QAS in RLSCs of DW'

The literature review in Chapter 2, Subsection 2.4.2.3 revealed that an information-centric integrated system is needed for QA in RLSCs of DW. The literature review further established that key aspects of this QAS are 'process', 'people', 'policy' and 'technology' which should be integrated within an information-centric environment for efficient and effective QA. Given these findings and reflecting the deductive approach of directed content analysis, the researcher identified data segments by engaging in detailed readings of interview transcripts that matched with the a priori codes of 'process', 'people', 'policy' and 'technology'. The researcher focused on identifying data segments that could not be considered under any of the above codes; however, none were found. The identified data segments closely related to each other were then grouped to form open codes, as shown in Table 4.2. In line with each open code's characteristics, they were grouped and presented under the *a priori* determined axial codes from the literature review (see Table 4.2). Finally, these axial codes were classified to form selective codes which were the final themes as presented in this section. Accordingly, the broad categories of themes related to the aspects of QA in RLSCs are presented separately under each phase of an RLSC of DW.

Table 4.2 Summary of the coding structure for establishing 'aspects of QA in RLSCs of DW'

Open codes	Axial codes	Selective codes
• Getting familiar with the job • Asbestos management • Deconstruction over demolition • Continuous risk assessment • Source separation • Appropriate storage and transportation of waste	Process	Building dismantling and on-site processing
• Skills and competency development • Licensing the workers • Supervising and monitoring	People	

Open codes	Axial codes	Selective codes
• Policies established internal to the demolition organisations • Policies established external to the demolition organisations	Policy	
• Technologies during the building dismantling and on-site processing	Technology	
• Minimising the risk of receiving mixed waste from demolisher • Initial inspection at the weighbridge • Off-site sorting and waste processing • Quality control	Process	Off-site waste processing
• Skills and competency development • Employee involvement • Supervising and monitoring	People	
• Policies established internal to the waste processing organisations • Policies established external to the waste processing organisations	Policy	
• Technologies during the off-site waste processing	Technology	

4.3.2 Themes' identification for 'epistemic uncertainties and IPMs for QA in RLSCs'

This subsection presents the identification of themes through both deductive and inductive approaches. Reflecting the deductive approach of data analysis, the researcher first found open codes for segments of data related to epistemic uncertainties and IPMs that were found in the OIPT studies. However, some epistemic uncertainties and IPMs were new as they were exclusively related to RLSCs of DW; thus, they could not be explained with concepts found in the OIPT literature. This then led to the development of new codes derived from the interview data, reflecting the inductive approach of the data analysis. Therefore, the final coding structure included codes from the OIPT literature and the interview data. The preliminary open codes were then grouped to form the potential axial codes. Finally, the axial codes closely related to each other were again grouped to form selective codes, which were the final themes of the study. Table 4.3 summarises the coding structure of epistemic uncertainties for QA in RLSCs of DW.

Table 4.3 Summary of the coding structure for identifying 'epistemic uncertainties for QA in RLSCs of DW'

Open codes	Axial codes	Selective codes
• Regulatory uncertainties • Incentivising uncertainties • Contractual uncertainties from FSC-upstream actors	Macro-level uncertainties	Epistemic uncertainties during building dismantling and on-site processing
• Management of demolisher's sub-contractors	Meso-level uncertainty	
• 'As-is' condition of the building • Management of contaminated/ hazardous substances • Health and safety concerns of the demolisher • Workflow uncertainties of the demolisher	Micro-level uncertainties	
• Regulatory uncertainties • Incentivising uncertainties • Contractual uncertainties from FSC-downstream actors	Macro-level uncertainties	Epistemic uncertainties during off-site waste processing
• Mixed waste received from demolishers	Meso-level uncertainty	
• Product description complexities • Human errors • Health and safety concerns of the waste processor • Workflow uncertainties of the waste processor	Micro-level uncertainties	

4.4 Aspects of QAS in RLSCs of DW

The literature review in Chapter 2, Subsection 2.4.2.2, found that an integrated system of process, people, policy and technology is needed for QA in RLSCs of DW. This section establishes how these aspects contribute to QA during two operational phases of RLSCs of DW: the building dismantling and on-site processing phase and the off-site waste processing phase.

4.4.1 Building dismantling and on-site processing phase

This subsection explains how aspects of process, people, policy and technology contribute to QA during the building dismantling and on-site processing phase in an RLSC of DW.

4.4.1.1 Process for QA

According to the study's interviewees, a systematic QA process occurs during the building dismantling and on-site processing phase. This process consists of a series of different practices that demolishers should follow during their work: becoming familiar with the job, asbestos management, deconstruction over demolition, continuous risk assessment, source separation and appropriate storage and transportation of waste. The following subsections explain each of these practices in detail, with support from excerpts from interviewees' interviews.

4.4.1.1.1 Becoming familiar with the job

The QA process during the building dismantling and on-site processing phase starts from the point of getting the job from a contractor/developer/client. In the foremost practice, demolishers seek to become familiar with the job before commencing dismantling. To learn about the job, they conduct site visits and thoroughly investigate the status quo of the building to be demolished and the job scope. Interviewee BD1 highlighted that a site visit before tendering is also important to price the tender with an understanding of the degree of difficulty in the job:

> We have a site visit and make sure the building is what it is. Then we do our assessments in detail. So, we've roved around a bit more freely to see if there's any risk, any danger, if it's going to be easy, and whether we need to do things differently from what we normally do. (Interviewee BD1)

Interviewee BD4 mentioned that doing a pre-demolition audit during initial site visits is important to increase the recovery rate of waste after dismantling. A pre-demolition audit allows demolishers to identify the non-hazardous materials that need to be removed from the building and to decide their potential reuse or disposal options. It also helps demolishers to identify and assess hazardous materials in the building to plan their management procedures. Furthermore, Interviewee BD1 stated that another purpose of the pre-demolition audit is to ensure that all the utility lines are disconnected, thus making the site safe for the commencement of the work.

Collecting drawings and asbestos registers is also imperative to become familiar with the job. As reported by Interviewee SG2, the asbestos register is a document that lists all the identified or presumed asbestos in a building. The contractor/developer/client should provide the demolisher with the asbestos register of the building to be demolished. If

not, the demolisher has the right to ask for it. If no asbestos register is available, Interviewee BD1 revealed the following:

> So that's up to the developers to give us the asbestos register, and we go from there. If not, we've just got to ascertain. We do our checks to see if there's asbestos, then we measure up how much asbestos; if there's any, note that down, and collate the information.

Similarly, the demolisher collects the 'as-built' drawings of the building to comprehend the job's complexity. Interviewee BD4 highlighted that a complete set of drawings allows demolishers to understand how the building was built, its materials composition and its structural integrity. Interviewee BD4 further revealed that having specifications in addition to drawings is beneficial if it is a high-rise building.

4.4.1.1.2 Asbestos management

Asbestos management is an important QA practice undertaken during building dismantling and on-site processing. Interviewee BD1 revealed that the demolishers receive and test samples to confirm the presence of asbestos in a building before commencing asbestos removal. Asbestos removal from a building is a complicated and dangerous process that should start only after informing the regulator (i.e., in this case, SafeWork SA) of the licensed asbestos removal work. For the entire duration of asbestos management, the demolisher should conduct air monitoring around the site to ensure that airborne asbestos fibres are not exposed to the atmosphere. Interviewee BD10 mentioned that after removing asbestos, the licensed asbestos removalist should label the asbestos-contained waste as per the 'Globally Harmonized System of Classification and Labelling of Chemicals':

> Once we have removed the asbestos, we normally have an asbestos bin on site. If the asbestos is plastic lined, it's wrapped up, and we seal it; bring it back to our yard; and have it in our asbestos bin. And when our asbestos bin is full, we then take it up north to dump or incoming as dumped up there in the asbestos dump. (Interviewee BD10)

Interviewee BD8 pointed out the importance of disposing of asbestos as soon as practicable at a site authorised to accept asbestos waste. Furthermore, after the asbestos removal work has been completed, a clearance inspection should be conducted to prepare a clearance certificate for the regulator before the workplace is re-occupied.

4.4.1.1.3 Deconstruction over demolition

Interviewees mentioned that instead of demolishing everything at once, giving consideration to deconstructing the building helps to prevent the destruction of components and materials that could be reprocessed. As a stringent regulatory requirement exists, demolishers often follow a systematic and sequential dismantling process to remove asbestos from a building. After removing asbestos, the demolisher soft strips (or undertakes 'selective deconstruction' or 'skims') the building before the mechanical demolition. In most cases, the demolisher employs a specialised sub-contractor for soft stripping. Interviewee BD3, who is a specialist in soft stripping, explained the process followed in soft stripping, as follows:

> So, we take out the windows, doors, and floorboards without breaking them; we strip the roof off. If there's a metal roof, we bring it back for recycling, and the ceiling; the tile roof gets disposed of with the bricks and the concrete. So, we are very careful with removing them. We transport them carefully. Then obviously, things get back to the yard, and we clean them up. They have nails and this and that and tidy them up and present everything for sale, so it's neat, tidy and easy.

Even if soft stripping occurs, Interviewee BD4 emphasised that demolishers in SA have no guiding benchmark to increase their understanding of the point of optimising deconstruction and demolition methods to yield maximum benefits. Moreover, Interviewee BD5 indicated that building deconstruction is more important for QA than selective deconstruction. However, due to the high consumption of time, money and labour, demolishers are not enthusiastic; even contractors/developers/clients in SA are not encouraged to undertake deconstruction.

4.4.1.1.4 Continuous risk assessment

Most interviewees revealed that dismantling a building is a high-risk job requiring continuous risk assessment. According to Interviewee BD1, it is important to assess the risks of a dismantling job throughout its execution to enhance the quality of the process while ensuring that no damage or harm exists to human beings (i.e., either workers or people around the site), adjacent buildings, and plant and equipment:

> In the middle of the process, we're always assessing to see what apparent dangers or risks are involved. Suppose the building is giving us grief in not coming down; the walls are not coming down. In such a case, it's going to be the priority that we're going to get it down safely without doing any damage to other properties or to people or equipment. (Interviewee BD1)

Interviewee BD4 emphasised that the demolisher experiences extremely high pressure from the contractor/developer/client to complete the job in a shorter duration. This burden hinders the continuous risk assessments of dismantling jobs. However, Interviewee BD3 revealed that demolishers are bound by the law to provide a safer environment for everybody regardless of time pressure from the contractor/developer/ client. Therefore, demolishers hold up the progress of the work if an apparent risk needing a prompt response emerges in the job. As Interviewee BD4 stated:

> It can be a slow process if you're particularly going to a building that is not coming down all right well. We've got to do it by hand, as I said. So, we've got to make sure that we do things right. So, it might take longer than we think. Sometimes we need to let the builder know what's going on.

Therefore, even if strict time constraints are present, the demolisher needs to plan his/her job at the beginning and continuously assess the risks inherent in the job throughout its execution to set in place appropriate actions in response to these risks.

4.4.1.1.5 Source separation

Interviewees identified that source separation is significant for QA during the building dismantling and on-site processing phase. Interviewees BD1, BD4 and BD7 highlighted that demolition sites have multiple bins or defined areas for the separation of each type of material. Therefore, allowing adequate space for source separation at a demolition site is a prerequisite. However, in the SA context, this has been a challenge. As stated by Interviewee BD1:

> We always separate the concrete, bricks, timber, green waste, trees and rubbish. All the elements, stainless steel and all that separate. The ordinary sheet iron goes in with the iron waste, but stainless steel is separated, copper is separated, brass is separated, and lead is separated. We have separate piles, so we load up [all] piles separately and don't mix them.

Therefore, on demolition sites, the most separated materials comprise concrete, bricks, metal and timber. Interviewee BD4 mentioned that source separation is particularly important to improve the quality of materials recovered after dismantling a building, thereby increasing the recovery rate and reducing the volume of residual waste in landfill:

> It is a must to do source separation. Suppose we do not appropriately separate the waste on site before getting to the off-site recycling facility. In that case, it will be contaminated and have poor-quality recycling materials. In the worst case, waste processors will also not accept contaminated waste; thus, the waste bulk will end up in landfills. (Interviewee BD4)

Interviewee WP2 revealed that source separation is also beneficial for the waste processor. He explained that, as source-separated waste is less contaminated, waste processing will be cheaper, easier and more efficient. Therefore, to encourage source separation, waste processors accept waste to MRFs only if it complies with their waste acceptance criteria. If not, they charge extremely high gate fees for the contaminated, unseparated waste.

4.4.1.1.6 Appropriate storage and transportation of waste

Most interviewees asserted that the appropriate storage and transportation of extracted materials to an off-site waste processing facility is a significant practice for QA. To shed further light, Interviewee BD2 underlined that the most important concern was to store and remove asbestos waste appropriately as soon as possible without allowing it to contaminate other recovered waste. Interviewee BD6 mentioned that asbestos should be transported to a licensed asbestos disposal site using only Environmental Protection Authority (EPA)-licensed vehicles.

The importance of appropriate storage of other recovered materials was also a point raised by several interviewees. Interviewee BD8 revealed:

> … certain products, obviously, we need to keep inside. So, we've got a storage yard. Obviously, doors, windows, floorboards, we need to keep dry, and some of the timbers are okay to keep outside, and I've got another storage facility. So, it's just a matter of whatever you need to keep dry or inside and, you know, rotate stock outside to keep it moving.

Therefore, after soft stripping and demolishing, the recovered components and materials, especially those that are weather prone, should be stored to avoid being exposed to unfavourable weather conditions. Furthermore, Interviewee BD10 stated that even if salvageable waste is stockpiled on the site, it should be positioned and arranged uniformly to avoid contamination. Furthermore, taking appropriate measures to minimise contamination of salvageable waste during transportation to an MRF is important. Interviewee BD8 specified that they avoid stacking waste higher than the maximum amount that could be loaded on a truck and always enclose waste while transporting, preventing exposure to the external environment.

4.4.1.2 People for QA

According to interviewees, the 'people' is an important aspect of QA during the building dismantling and on-site processing phase in RLSCs of DW. The interview

findings indicated that demolishers should ensure that people engaged in this phase are accountable for QA through 'skills and competency development', 'licensing the workers', and 'supervising and monitoring', as discussed in the following subsections.

4.4.1.2.1 Skills and competency development

Several interviewees (i.e., BD1, BD2, BD6 and BD10) recurrently mentioned that, for people engaged in the building dismantling and on-site operations, years of practical experience in the field are more important than theoretical and explicit knowledge. Given this point, Interviewees BD1 and BD2 emphasised that they are always looking for experienced workers to become part of their organisations with their skills evaluated based on a specific evaluation criterion. Interviewee BD1 further highlighted that the demolition organisations conduct extensive training programs even after recruiting experienced workers. The existing regulations allied to SafeWork SA mandate training for workers who specifically carry out licensed asbestos removal work in a demolition project. Furthermore, Interviewee BD4 mentioned that as per the requirements in AS 4801:2001 (Occupational health and safety management systems), recurrent training programs should be conducted for demolition workers to ensure that their skills are contemporary:

> We have training every six months. We have to keep AS 4801 up to date. That's why we have these quality control procedures and training programs. I have a training matrix. So, I know [for] everybody, when they did the last standard operating procedures or their certificates, what they can drive [and] if they need to come up for more training. (Interviewee BD4)

Given this point, the demolition organisation, as the employer, has a responsibility to train and upgrade workers' skills and competencies: however, if the organisation is certified with a reputed QAS, this becomes mandatory.

4.4.1.2.2 Licensing the workers

Interviewees pointed out that two types of asbestos are encountered during building demolition. According to Interviewee SG2, these are:

> Friable asbestos – The products containing friable asbestos have loosely packed asbestos fibres. Therefore, they are more dangerous than other types as these loose asbestos fibres can be easily released.
>
> Non-friable asbestos – This type of asbestos is tightly bonded to cement or similar material-based components. Thus, they are unlikely to be released into the air unless they are disturbed, damaged or badly weathered.

As per the SA Work Health and Safety Regulations 2012, workers assigned to remove asbestos should have a licence to remove more than 10 m^2 of non-friable asbestos-containing material. Depending on the form and quantity of asbestos, the two licence classes are:

> Class A licence: To remove all asbestos-containing materials, including friable asbestos materials
> Class B licence: To remove any amount of non-friable asbestos

According to Interviewee BD3, if workers have asbestos removal licences, firstly, their job safety is being assured as they are well informed on how to be protected potentially being exposed to asbestos. Secondly, the entire licensing process improves workers' knowledge at demolition sites on how to manage asbestos safely which is a significant practice for QA during the building dismantling and on-site processing phase (see Subsection 4.4.1.1.2).

4.4.1.2.3 Supervising and monitoring

Many interviewees raised the need for overseeing the execution of operations during the building dismantling and on-site processing phase. Interviewee BD1 claimed that the organisations' managers need to be on site nearly every, day instructing and directing subordinates, even if those workers were experienced and well trained:

> We're a QA company; we've got procedures to abide by. When I go on the site, I fill out JHA (job hazard analysis) paperwork. I have the paperwork in place with their names on it, who's on site, who's doing what, and they all know what they've got to do by filling out paperwork, having the safety here, and generally making sure everything runs smoothly. (Interviewee BD1)

Interviewee BD4 asserted that asbestos removal supervisors have a mandatory role in overseeing the licensed asbestos removal work per the Work Health and Safety Regulations 2012. According to this regulation, as Interviewee BD4 further disclosed, supervisors must be readily available to workers carrying out asbestos removal work.

4.4.1.3 Policies for QA

Interviewees identified 'policies' as another aspect contributing to QA during the building dismantling and on-site processing phase. From analysis of the interviews, policies established both internally by demolition organisations as well as externally were found to facilitate QA, as discussed in the following subsections.

4.4.1.3.1 Policies established internal to demolition organisations

All interviewees confirmed that demolishers always work to deliver a quality service for clients through maintaining the highest performance standards, professionalism and customer service. Most large-scale demolishing organisations have obtained third-party accreditation for their QASs. For instance, Interviewee BD4 mentioned that his organisation's third-party accreditation to AS/NZS ISO 9001:2008 QAS underlines how the organisation is committed to providing quality service while engaging with clients to understand their specific needs. Interviewee BD4 further stated that an organisation-wide quality policy and, thereby, some supplementary documents were developed as part of this QAS, considering it as a guide to continually improving the quality of their work:

> Different demolishers got different accreditation. We've got ISO 9001:2008. Based on this, the company has a quality policy. To achieve this quality policy, the company has also developed a business management system manual, clear procedures outlining quality approach and operations, detailed quality work instructions, and customer satisfaction surveys. (Interviewee BD4)

Together with the quality policy, these supplementary documents codify all the rules, guidelines and frameworks followed to achieve QA by demolishing organisations. Interviewee BD2 asserted that the organisational quality policy and its subordinate documents become the framework for all other project-specific plans and procedures. Interviewee BD2 also mentioned that demolition organisations have a separate environmental policy and a work, health and safety policy which, respectively, present the basis for the development rules and guidelines related to the organisation's environmental management and health and safety management. However, it is not always essential to have third-party accreditation to develop these policies in an organisation. For instance, Interviewee BD3 highlighted that his organisation did not have a third-party QA accreditation as it required a huge financial commitment. Despite this, the organisation had an extensive quality policy, through which most of the secondary documents, guidelines and frameworks were developed to support the organisation's QA.

While the policies mentioned above are common to every project, project-specific documents for QA are also required. Interviewee BD1 stated that they prepare a demolition management plan, asbestos removal control plan, safe work method statement and sub-contracts for each project. Some of these documents need to be

prepared due to stringent regulatory requirements (e.g., asbestos removal control plan). In contrast, others should be developed as per organisational requirements to plan for the successful completion of the project. These documents should be developed before the commencement of building dismantling; thus, they provide useful guidance for demolishers to successfully execute their job within the assigned period. For instance, Interviewee BD1 explained the importance of a demolition management plan as follows:

> Before any job, I make up all the safe work method statements, asbestos removal control plans, demolition management plans and sub-contracts. Here, the demolition management plan is the most prominent document informing everybody of the site's job scope. It is a detailed document with different sections. It contains separate sections such as safety and environmental risk control, noise and vibration control, dust control, demolition, resource allocation, safety checklist and management.

In summary, demolishers should develop organisation-based and project-based policies for QA during the building dismantling and on-site processing phase. Most demolition organisations, especially large-scale ones, have developed these policies based on the requirements of third-party accreditation. At the same time, demolition organisations with no such accreditation also have internal policies that direct their process quality.

4.4.1.3.2 Policies established external to demolition organisations

In SA, the EPA SA and SafeWork SA are the state government organisations that regulate demolishers. These regulators have acts, regulations and codes of practice that influence QA during the building dismantling and on-site processing phase. For instance, Interviewee SG3 revealed that the EPA regulates the environmentally significant processes of any industry, complying with the *Environmental Protection Act of 1993*. Several regulations, policies and standards have been developed based on this Act, and among them, some explicitly influence the QA of RLSCs of DW. Interviewee SG3 pointed out, for instance, that the landfill levy, which is the most crucial influencer for the demolisher's QA, is regulated through the Environment Protection Regulations 2009:

> We have key legislation, policies and regulations that come from it, such as the Environment Protection Regulations 2009, which effectively set out the waste levy, a market-based trigger to increase the cost of landfill disposal, with the intent of increasing resource recovery and recycling. (Interviewee SG3)

Interviewee SG4 mentioned that the Environment Protection (Waste to Resources) Policy 2010, which originated from the Environmental Protection Act SA, also acknowledges the different types of waste that are the only types of waste that are allowed to be disposed of in landfill. With this policy, the EPA SA informs internal stakeholders that all the prohibited materials should be processed without being directed to landfill.

Both EPA SA and SafeWork SA regulate asbestos management in demolition work. Interviewee SG2 highlighted that SafeWork SA is responsible for administering asbestos removal per the *Work Health and Safety Act 2012* and the Work Health and Safety Regulations 2012. Furthermore, SafeWork SA has developed two codes of practice that provide practical information and guidance on meeting their regulation's requirements that relate to asbestos management: (1) 'Code of Practice on How to Manage and Control Asbestos in the Workplace' and (2) 'Code of Practice on How to Safely Remove Asbestos'. These codes are not mandatory but provide information for demolishers for appropriately and safely managing asbestos.

Interviewee SG1 stated that demolishers must obtain licences from EPA SA for asbestos transportation and disposal and for reprocessing waste on site or off site. Furthermore, SafeWork SA issues asbestos removal licences for demolishers per the requirements in the *Work Health and Safety Act 2012 (SA).* Therefore, all the Acts, regulations, codes of practice and licences are policies developed external to the demolition organisations but that directly influence their QA.

Interviewees identified the demolition contract as an important document that includes information required for QA:

> So, there's a contract that deals with all the contractual clauses. And there are appendices to the contract, typically a program that outlines when they can start and when they must finish. And then the contract says what happens if they do not do that. Then the other key section is the scope of work. (Interviewee BD4)

A typical contract document provides the demolisher with the drawings, demolition specifications, geo-tech reports, bore logs and asbestos register. Notably, it also includes the demolition approval received by the contractor/developer/client from the local council (i.e., local government). This demolition approval highlights some conditions that provide important information for demolishers on how the demolition procedure should be conducted. Interviewee LG03 pointed out that some local government

agencies add advisory notes to the decision notice, notifying demolishers that they must adhere to Acts and regulations when undertaking their work and managing waste. In addition, supplementary conditions are included in the contract if the client or architect has specific requirements about the dismantling or waste management procedures. For instance, Interviewee BD4 pointed out that when he was engaged to dismantle a heritage-listed building, the architect wanted most materials and products recovered after the dismantling. Due to this, the builder developed the contract, including the conditions specifying the requirement to carefully dismantle the building. However, due to these requirements, this project was expensive and extended for a lengthy period.

4.4.1.4 Technologies for QA

According to interviewees, very few new technologies are used for QA during the building dismantling and on-site processing phase in RLSCs of DW. Interviewee SG1 revealed that demolition organisations in SA are steadily transforming to adopt innovative technologies, but they are still in the early stages of this transformation. However, the sporadic growth and fast execution of infrastructure and construction projects in SA compel demolition contractors to adopt more advanced technologies to deliver quality output. However, these technologies are only being used for asbestos management in dismantling projects.

Interviewee BD3 highlighted that as asbestos management has stringent regulatory requirements, his/her organisation sets up air monitoring across the dismantling sites during asbestos removal operations. For this, they use advanced static and positional air sampling instruments to take samples at fixed locations across an area during asbestos removal work. The collected air monitoring samples are then analysed by a National Association of Testing Authorities (NATA)-accredited laboratory. Interviewee BD1 mentioned that dust monitoring equipment is also used in large-scale dismantling projects.

Interviewee BD5 stated that most large-scale demolition organisations use near-infrared handheld analysers to identify asbestos-containing materials in a building. This interviewee explained the purpose of this equipment as follows:

> It is not always practicable to have lab-based analysis to detect asbestos in complex and large-scale projects where much asbestos is present. Generally, a lab-based analysis would cost us more and be time consuming. Therefore, to make our job

> easy and ensure the health and safety of the working environment, we are using a near-infrared analyser to identify asbestos rapidly.

Interviewee BD5 further mentioned that they plan to use a site proximity warning system in their future demolition projects. This system uses radio-frequency identification (RFID) detectors to enhance site safety by avoiding accidents during dismantling operations. These are a type of early warning system making workers aware of risks at the site.

In addition to the above-mentioned innovative technologies, Interviewee BD1 pointed out that demolition organisations also use conventional equipment like crushers, pulverisers, high-performance breakers, vibro rippers, cranes, elevated platforms, excavators and bulldozers.

4.4.2 Off-site waste processing phase

This subsection explains how aspects of process, people, policy and technology contribute to QA during the off-site waste processing phase in RLSCs of DW.

4.4.2.1 Process for QA

Similar to the building dismantling and on-site waste processing phase, a systematic process is used to assure quality during the off-site waste processing phase. This process encompasses a series of practices: minimising the risk of receiving mixed waste from demolishers; initial inspection at the weighbridge; off-site sorting and waste processing; and quality control. The following subsections explain each of these practices in detail.

4.4.2.1.1 Minimising the risk of receiving mixed waste from demolishers

All interviewees emphasised that the process quality of the waste processor primarily depends on the quality of waste that enters the MRF. Therefore, several interviewees highlighted different strategies that waste processors employ to ensure that they receive uncontaminated and segregated waste streams from the demolisher.

Interviewee WP3 stated that most large-scale waste processing organisations have a separate designation called Accounts Manager, with this person having the primary role of building and maintaining strong relationships with the demolishers (input customers of waste processors). The Accounts Manager introduces new customers to their business and proactively follows up with them until they take their waste to the MRF. Furthermore, these Accounts Managers also actively engage with and make sure that the

MRF is receiving sorted and uncontaminated waste, which complies with the waste acceptance criteria of the waste processor:

> Accounts Managers will get to the job site to ensure the demolisher will come to us. Yeah, so they're very proactive in that sense. So, all the customers who come in have a cabinet for a set of sales. So one, they're responsible for setting the price for that customer. And two, they're accountable for everything that happens with that. And the idea is you have to have good relationships with them so that when things go wrong or go right, you've got someone who understands their business and can mediate between our business and their business. (Interviewee WP3)

Interviewee WP2 also reported that his/her organisation forms contracts with some large-scale demolishers in SA. These large-scale demolishers mostly engage in major dismantling projects that last a considerable time, and they generally provide services to Tier 1 builders in SA. By forming contracts with demolishers, waste processors receive an assurance that they will receive well-sorted waste for an extensive time.

4.4.2.1.2 Initial inspection at the weighbridge

Interviewees revealed that when a waste load is transferred to the weighbridge of the MRF, the waste processor conducts an exhaustive examination to ensure that it is not contaminated. Interviewees WP1, WP2 and WP3 highlighted that waste received at the MRF goes through two main inspection points. Interviewee WP3 explained this in detail:

> All the loads get checked, but some would get checked a bit more rigorously than others. And then the weighbridge operators, who we call customer service representatives, will inspect it from the elevated viewing platforms. And then we have a traffic person or spotters who will check it once it's tipped off. Spotters will go through the load visually; [they'll] probably spend two, three or four minutes walking over it, looking at it, and assessing it.

Therefore, 'customer service representative' and 'spotter' are the two roles assigned to inspect waste loads at the weighbridge. Furthermore, Interviewee WP2 mentioned that a few closed-circuit television (CCTV) cameras are also fixed at the weighbridge to inspect each load. The waste load is accepted for further processing only if these inspections confirm that it is free from contaminants. Interviewee WP1 stated that if the waste load contains more than 5% of non-compliant materials, the waste load will not be accepted and demolishers will be asked to take it and dispose of it at a suitable disposal site.

4.4.2.1.3 Off-site sorting and waste processing

Interviewees reported that even if demolishers do source separation, waste processors carry out off-site sorting again before introducing waste to the processing plant. Interviewee WP5 noted that as waste sorting and processing occur at once inside the same plant with a series of continuous stages, this process is known as 'waste reprocessing':

> It's quite a sophisticated process. So, you know, there's probably six or seven steps in the chain that ensure we've got a quality product at the end. (Interviewee WP5)

Interviewee WP3 mentioned that, despite using their hands, waste processors always sort waste using machinery as much as possible to make the process more efficient and effective. Interviewee WP3 explained how waste processing is undertaken in a typical plant, but noted that this could vary depending on the volume of waste received by the plant. Accordingly, tipped materials at the drop-off facility are first introduced for trommel screening for those 40 mm in size. Trommel fines of 0–40 mm are then further screened to remove long parts and are transferred under an over-band magnet to remove ferrous metals. The remaining trommel fines are next subjected to a flip-flop screen that sieves 0–10 mm fines. The air-classification unit then separates the 10–40 mm heavy residues ('heavies') from light residues. The oversized materials (i.e., over 40 mm in size) are conveyed to the elevated picking station, where each picker is assigned to pick separate fractions of materials, placing them into a corresponding bay beneath the picking station. The waste pickers generally separate cardboard and paper, polyvinyl chloride (PVC), wood, etc. The remaining oversized materials then pass under an over-band magnet that removes all the ferrous metals. The residual is next introduced to overbuilt blowers that separate clean hardcore from light residue. After this exhaustive mechanical separation process, Interviewee WP3 revealed that his organisation ships all the ferrous metals to external specialists for further processing. The sorted inert fractions are recycled into rubble, road-based materials and clean, wet and mixed fill. The trommel fines, which are a byproduct of trommel screening, are used as alternative daily cover material at landfill sites.

4.4.2.1.4 Quality control

Interviewees stated that after producing reprocessed products, waste processors conduct tests before dispatching these products to the secondary market. Interviewee WP5 reported that his/her plant had an *in situ* lab to easily test the reprocessed products:

> The lab work here targets monitoring our end-products to ensure they reach our customers and perform as expected. An on-site lab can analyse materials faster and receive results more quickly. (Interviewee WP5)

Interviewee WP1 elucidated that waste processors test reprocessed products against the SA Department for Infrastructure and Transport (DIT) sampling specifications. They generally test reprocessed products for their density, versatility, durability and environmental sustainability. If products do not meet the standard requirements, the secondary market will not sell them. A group of specialists is assigned to conduct these tests in a waste processing organisation:

> We have an Environ team who do some testing on products. And we also have a company called … who come in and test the stockpiles, which is independent. So that's a third party. So that no one can say that we rig the testing or whatever, we get a third party to come in twice a week. And then, those results get sent to the Environ team. And they're tested against DIT standards for the product. (Interviewee WP1)

From the above points, it is evident that waste processing organisations conduct periodical sampling and testing to ensure that their products meet end-users' requirements.

4.4.2.2 People for QA

As in the building dismantling and on-site processing phase, the 'people' is an important aspect of QA during the off-site waste processing phase. Accordingly, 'skills and competency development', 'employee involvement' and 'supervising and monitoring' are paramount for QA during this phase, as discussed in the following subsections.

4.4.2.2.1 Skills and competency development

Interviewees highlighted that even if advanced plants and machinery are used, human involvement plays a significant role in waste processing. Therefore, employing experienced labour and developing their skills and competencies throughout their job is important. For instance, Interviewee WP1 pointed out that most workers in waste processing organisations start their careers as waste pickers, and then, with time, they gain expertise in the field. Interviewee WP5 raised the importance of training and skill development of workers in waste processing. Consequently, waste processing organisations encourage workers to obtain relevant licences for their jobs from authorised third-party organisations. In addition, in-house training programs are

periodically scheduled to enhance the knowledge and skills of workers on contemporary techniques and technologies related to their work:

> We use a third party for tickets for the loader, excavator and dozer, etc. Same thing with first aid certificates and asbestos. But yeah, we use a third party for anything that's really specific, or there's a legal requirement for training to a certain level. But we'll do more of the vocational training with internal modules, which we build up ourselves. That's like … PowerPoint, and then it's got a questionnaire at the end, and we all … so when someone starts on the job, we buddy them up. (Interviewee WP5)

Interviewee WP3 revealed that his company was using a separate cloud-based software system called 'Skytrust' to manage employees' licences, training and certification. All their internal safety systems and training programs were built into this software; thus, it has significantly helped to effectively and efficiently manage the organisation's human resources. For instance, this software included a skills matrix that identifies the skills and competencies required for each employee/job and how to achieve them. This system has helped the organisation to track mandatory staff training and comprehensive human resource profiles.

4.4.2.2.2 Employee involvement

All interviewees mentioned that employee involvement and commitment from top management to operational-level workers are paramount for QA during the off-site waste processing phase. Interviewee WP6 pointed out the importance of having a decentralised culture within waste processing organisations where activities, particularly planning and decision making, are delegated among many teams rather than being done by a single team. Consequently, each employee in the organisation is responsible for his/her work; thus, the organisation advocates to improve the quality of their jobs. Interviewee WP3 also mentioned that waste processing organisations often conduct different types of meetings involving employees, such as daily toolbox meetings, weekly QA meetings and monthly top management meetings. All these meetings promote knowledge sharing among employees and a strong awareness of the issues and status quo of the organisation:

> We have regular toolboxes; generally, there is a reason for them. They may be procedural, or there might be an incident, or whatever when you try anything. They're quite frequent; they're probably once every two weeks. They might have two in one week. (Interviewee WP3)

Top managers' influence and involvement in organisational performance are the key driving forces for waste processing organisations to be competitive in the industry. For instance, Interviewee WP1 pointed out how the top management of his organisation was contributing to QA as follows:

> I've never worked for a company that spends so much money, time and energy on training. That's a credit to the owners, which is noticeable, and it's at all levels. So, they pay for training for me. I don't think they've ever said 'no' to not being trained, provided it fits the vision.

Thus, it is understandable that, despite the many skilful workers present in waste processing organisations, top management and employee involvement and commitment are crucial for successful QA in RLSCs of DW.

4.4.2.2.3 Supervising and monitoring

According to interviewees, supervision and monitoring are also important to ensure the quality of off-site waste processing. Interviewee WP3 mentioned that even if waste processing constitutes machine-based mass production, 75% to 80% of processing is labour intensive. Consequently, human errors are common throughout the production process. Therefore, Interviewee WP3 raised the need for supervision and monitoring throughout waste processing. As an example, Interviewee WP3 highlighted the extensive supervision structure allied to waste picking, a significant stage in waste processing, as follows:

> Within the structure, there's a picker, there's a senior picker, there's a team leader picker, and then there're supervisors, and there's a site supervisor, and then there's a team. So, you'd be a picker in your first six months, and you're not expected to know too much. It's really the picking. And then, once you understand all the magnet side of the role, you become a senior picker, and then you have a team leader picker who looks up, and there's also a CCTV, which would be a form of supervision.

Therefore, this statement emphasises that even if employees are experts and committed to being involved in their job, supervision and monitoring play a prominent role in QA during off-site waste processing in RLSCs of DW.

4.4.2.3 Policies for QA

As in the building dismantling and on-site waste processing phase, the 'policies' that contribute to QA during the off-site waste processing phase can be recognised as policies internal and external to the waste processing organisations, as discussed in the following subsections:

4.4.2.3.1 Policies established internal to waste processing organisations

As in the case of demolishers, large-scale waste processors have obtained third-party accreditation for their organisational QASs. Interviewee WP3 applauded the benefits that waste processing organisations could gain from quality-certified systems. For instance, Interviewee WP3 highlighted that an internal quality policy was developed in his/her company based on the requirements of the AS/NZS ISO 9001:2008 certified QAS. This quality policy was a formal statement developed with the best intentions of the company. However, the policy on its own was absolutely nothing without supplementary documents that codified the working procedures of the waste processing plant:

> You need to have the policy to tick the box. Then I think that's a more basic level of why you have it. It's a statement of intent; it's a guideline. And then it's probably more important what happens after that. So how does the policy get, how does the rubber hit the road, and how does it play out at that level? So, policies are sort of about the motherhood statement, the signal of intent. Then underneath that, you've got your procedures, you've got the safety systems, you've got your training, you've got your working orders, all of that is holding you to that account. (Interviewee WP3)

Interviewee WP6 identified 'waste acceptance criteria' as a policy developed by waste processing organisations and approved by the EPA to accept waste streams from demolishers. After complying with the waste acceptance criteria, the demolisher must pay the gate fee (or tipping fee), the charge levied by the MRF upon the waste accepted. Thus, regardless of organisational size, every waste processor has a gate fee and waste acceptance criteria that persuade demolishers against transferring mixed waste to waste processors.

Interviewee WP1 also highlighted that most large-scale waste processors form contracts with large-scale demolishers whenever a complex project is demolished. Furthermore, Interviewee WP2 revealed that some waste processing organisations enter into business partnerships with demolishing organisations. These business partnerships allow them to grow and learn collaboratively. Through these partnerships, both organisations can access more knowledge, expertise, resources and finance to make quality products for a broad end-user market. Therefore, a business partnership agreement is a policy that both waste processors and demolishers could adopt which would remain in place for a long time, enabling them to effectively and efficiently reach cooperative quality goals.

4.4.2.3.2 Policies established external to waste processing organisations

All interviewees expressed the view that, as with demolishers, the QA of waste processors is also influenced by different Acts, regulations and standards of regulatory bodies. For instance, Interviewee SG1 highlighted that the *Environment Protection Act 1993* mandates that waste processing organisations receiving more than 100 tons of waste during a year must have an EPA-issued licence. Furthermore, the *Work Health and Safety Act 2012*, administered by SafeWork SA, also regulates waste processors to ensure that the working environment has no health and safety risks, especially the presence of asbestos in mixed waste received by the facility. Similarly, all the regulations, standards and codes of practice that originated from these Acts also influence the QA of waste processors. For example, according to Interviewee SG2, the EPA has developed the Waste-derived Fill (WDF) Standard which clarifies to the industry the processes to be used to recover waste used as a fill material. This standard includes information for waste processors on QA measures, demonstrates the WDF's beneficial properties and minimises the risk of environmental harm during processing.

According to interviewees, the DIT uses different specifications, such as national and Austroads specifications, to inform waste processors of the quality requirements to which they must adhere when producing reprocessed products. The DIT has also developed a master specification that acknowledges the standard quality and performance requirements expected from materials used in infrastructure projects. This master specification informs the industry of the materials that must be incorporated for each element, the processes used to obtain consistent products and the tests required to find impurities and contaminants. Interviewee WP10 stated that the sustainability specification is part of this master specification, which includes what elements, what reprocessed products and the amount of products which the client expects to incorporate into his/her project. The master specification, including the sustainability specification compiled as a materials supply contract, is provided to waste processors informing them of the quality criteria to which they should adhere when delivering materials to the project. Therefore, these sub-contracts and specifications are policies that provide waste processors with important information to assist them to in produce reprocessed products that fulfil market expectations.

As mentioned above, SA lacks specifications exclusively for reprocessed products but has specifications for virgin materials. Interviewee SG1 therefore highlighted that the

industry focuses on developing product performance specifications rather than recipe specifications. This emphasises that waste processors are allowed to develop internal specifications for their products but must obtain authorisation from the DIT before introducing them to the market. Interviewee WP5 also emphasised that waste processors always seek end-user feedback for further improvements to their reprocessed products. According to Interviewee WP9, the DIT also provides a review for waste processors if reprocessed products, as per their test results, do not comply with the specified quality criteria. The DIT also avoids selecting suppliers for future projects if they have previously supplied non-conforming products. Therefore, end-user feedback is an important policy for waste processors when making decisions to strategically improve their internal QA process.

4.4.2.4 Technologies for QA

Interviewees revealed the different types of technologies used for QA during the off-site waste processing phase. Interviewee WP1 mentioned that the nature of waste processing was machine-oriented; thus, they always sought sophisticated technologies to improve the performance and quality of their work. Interviewee WP1 explained the importance of technologies for waste processing as follows:

> Technology will impact [on] the quality of our process. It'll allow us to identify materials more quickly and with more assurance. For example, we train our people at the weighbridge to recognise asbestos but only do it through visuals. But now we have given them [near infra-red] NIR spectrometers, and now they'll point it at the asbestos and tell you if it's asbestos or not. So, technologies will improve that part of the business.

Waste processors monitor the composition of waste loads received from demolishers because if any contaminant enters the MRF, it will affect the quality of a batch of reprocessed products. Therefore, waste processors seek to incorporate many advanced technologies at the weighbridge to confirm that incoming waste loads are free from asbestos and other destructive contaminants.

According to interviewees, a sophisticated waste processing plant uses many technologies such as blowers, magnets and screens to sort and process waste. Interviewee WP2 elucidated that the advancement of these technologies would change depending on the plant's size and the waste processor's financial capabilities. For example, Interviewee WP1 stated that some waste processing plants use optical sorters to sort commingled materials during the last stage of waste processing. These optical

sorters help MRFs to reduce their reliance on the workforce to sort various materials, at the same time making the entire process more efficient and effective. As elucidated by Interviewee WP1, integrating this technology with artificial intelligence (AI)-enabled sophisticated monitoring and control systems presents an opportunity.

Even though many technologies have been adopted for QA during the off-site waste processing phase, interviewees also identified a few criticisms that are worth highlighting. Accordingly, Interviewee WP7 revealed that these innovative technologies are highly expensive, and thus the waste processor must have a sound financial capability to invest in them. Therefore, most small and medium-scale waste processors are not financially able to adopt advanced technologies. Interviewee WP9 also highlighted that as these technologies need skilled operators, most waste processors are reluctant to adopt them as hiring expert operators would cost them more.

4.5 Epistemic Uncertainties that Lead to Information Processing Needs (IPNs) for QA in RLSCs of DW

The study identified 16 epistemic uncertainties, eight each from the building dismantling and on-site processing phase and from the off-site processing phase, leading to information processing needs (IPNs) for QA in RLSCs of DW. The following subsections discuss those epistemic uncertainties in detail.

4.5.1 Epistemic uncertainties during the building dismantling and on-site processing phase

The epistemic uncertainties during the building dismantling and on-site processing phase, as identified by interviewees, are discussed in the following subsections. The current study found three macro-level, one meso-level and four micro-level uncertainties encountered for QA during this phase.

4.5.1.1 Macro-level uncertainties for QA

As per the analysis of the semi-structured interviews, the study found three macro-level uncertainties that demolishers encounter for QA. The following subsections explain each of these uncertainties in detail.

4.5.1.1.1 Regulatory uncertainties

Although many legislative instruments influence demolishers, none regulate most of their significant work except asbestos removal and waste transportation. Interviewee

SG2 stated that no legal instrument administers source separation or dismantling during this phase in RLSCs:

> The regulation under EPA only considers the waste once it leaves the site. Because after leaving the site, only EPA consider[s] it as waste. After that, only reprocessing and licensing can happen, but if it's processed on site, it goes straight to the quarry and [it is] use[d] for rehabilitation without further processing, licence or regulation. (Interviewee SG2)

As no legislative influence is in place, no state government agencies have developed standards or guidelines to provide useful information for demolishers in carrying out their work. Even though mandatory requirements exist through legislative instruments for all MRFs to be licensed by the EPA, demolishers have no such requirement unless they engage in asbestos removal, transportation, disposal and on-site or off-site reprocessing. Even in asbestos management, Interviewee BD4 indicated that the existing legislative requirements in the *Work Health and Safety Act 2012* continue to change, creating epistemic uncertainty for demolishers. Interviewee BD4 further explained this in detail as follows:

> There are always changes going on in the Act. They've just changed the rules. Now, I'm a qualified asbestos assessor. And SafeWork now just changed the rule to say you got to employ someone different to do assessing. Therefore, now I can't assess my people because there's a conflict of interest. So, now we employ a separate company.

Local government agencies have a development plan developed by customising the provisions in the *Development Act 1993* as per their administrative area's social, cultural, geographical and financial conditions. Through this, local government agencies state that approving demolition needs to be undertaken through a building approval. However, when approving the demolition, local government agencies rarely ask for information about the waste management procedures of the project. Interviewee LG2 explained:

> The basic assessment is undertaken for the application and, generally, that will be granted consent with conditions. So those conditions generally do not ask you to reuse materials in this way, or [that] you have to recycle them.

At the time of the current study's data collection, local government agencies administered the *Development Act 1993* to approve development applications. Interviewee LG1 mentioned that this Act did not include a single provision related to demolition. However, after 19 March 2021, the Development Act was transformed into the *Planning, Development and Infrastructure Act 2016*, enabling every local

government agency to work under one development plan. Notably, the new Planning, Development and Infrastructure Act also does not consider demolition as part of development; thus, demolishers do not need to apply for demolition approval:

> In that new Act, demolition is not a form of development. So, they're talking about having most demolitions not require[ing] any approval in the new planning system. In this case, local government agencies would have no statutory responsibility for demolition whatsoever. (Interviewee LG1)

Interviewee LG1 added that when existing regulatory instruments do not completely regulate the building dismantling and on-site processing phase, regulatory bodies are not actively monitoring the demolisher's work except for asbestos management. Therefore, in summary, due to the gaps in the existing regulations, issues with the demolition approval process and improper monitoring of regulatory bodies, demolishers encounter regulatory uncertainties for QA.

4.5.1.1.2 Incentivising uncertainties

Interviewees mentioned that government agencies are influencing internal stakeholders in RLSCs by providing assistance, advice and guidance on waste management. Interviewee SG1 pointed out that Green Industries SA (GISA), as the custodian of SA's waste strategy, has a role in informing internal stakeholders about waste management and resource recovery and providing assistance to industry practitioners whenever they encounter issues related to waste management. Even though GISA educates and guides actors engaged in other waste management streams, it is not dynamically involved in CDW management. For instance, Interviewee LG2 revealed that GISA, together with Renewal SA and the Property Council of Australia, has developed 'Better Practice Guide Waste Management for Residential and Mixed-Use Developments' to support developers in developing waste management plans for new developments. Local government agencies ask for this waste management plan when providing approvals for new developments. Therefore, clients seek advice and support from non-governmental organisations (NGOs) with expertise in waste management to develop these waste management plans. However, similar requirements are not in place for demolition approval, and thus local government agencies have minimal involvement in the DW management sector.

Several interviewees highlighted that NGOs are involved in subsidising sustainable production, consumption and waste reduction in SA. However, NGOs only engage in

waste management if they receive financial impetus from state government agencies. Interviewee BD5 shared one of his experiences in which an NGO monitored the demolisher's work in a government-led bushfire clean-up project in the Adelaide Hills. Due to this government's incentivising strategy, the demolition project had an extremely high recovery rate of 72%. However, Interviewee BD5 emphasised that this was an uncommon example as government in SA rarely commits funding to incentivising for DW management.

Furthermore, interviewees voiced their criticism that local government agencies have a significant role in managing kerbside waste, food waste and other hard waste streams but not construction and demolition waste (CDW). Many guidelines, workshops and online awareness programs have been developed by local government agencies to inform the community about the importance of source separation and recycling other waste streams. This was further confirmed when referring to the websites of local government agencies. Every local government agency has an informative website that communicates best practices of other waste management streams through animated videos and frequently asked questions-type guidelines. Notably, CDW management does not have a similar comprehensive description.

4.5.1.1.3 Contractual uncertainties from forward supply chain (FSC)-upstream actors

The contractual uncertainties from forward supply chain (FSC)-upstream actors are a type of macro-level uncertainty encountered by demolishers when commencing a dismantling job. Before starting the dismantling, the contractor/developer/client offers an 'invitation to tender' for demolishers and asks them to submit a quote for the work. According to Interviewee BD12, the contractor/developer/client generally seeks to employ demolishers who have done their previous jobs. They often select the lowest quote with the shortest time, intending to make profits from the work. Thus, only a simple evaluation process is typically done to choose a demolisher for a dismantling job. So, in most cases, the contractor/developer/client does not provide much information about the project when they issue the 'invitation to tender' for demolishers to consider when preparing their estimates for the job.

According to Interviewee BD12, the contract between the demolisher and contractor/developer/client is simple and reasonably similar for every project. This contract does not indicate any conditions related to DW management unless the project

is planning to apply for a Green Star rating or if it is a heritage-listed building (as per the regulatory requirements). Interviewee BD1 pointed out that the contractor/ developer/client is only concerned about the money and time when establishing a contract with a demolisher. Therefore, through a contract, they force the demolisher to complete the job within minimum cost and minimum duration. Other than these factors, they are not concerned about how things will happen at the site:

> Developers just want the job done quickly. It's quick, quick, with them. And the minimum amount of money they want to spend, the better it is for them. The developers sometimes don't look at how complicated some things are. And I think some developers want to take a shortcut in getting the process done. It costs more to have one machine, and I'll have to send out three or four guys and a truck. It's more expensive to strip a house than have a machine and a truck and smash it. But there are also time constraints as well. (Interviewee BD1)

Notably, Interviewee BD3 reported that, even if the government attempts to promote recycling in SA, the government itself is the worst offender when a public demolition project is involved. In particular, Interviewee BD3 explained:

> They say they want to recycle, but they will put a job out. That's been built to be a house, or when it is widening the road, they've got to order [that] your house [is taken] that has been sitting empty for two years. And then they give a demolition company a whole week to do it. It's ridiculous. Whereas if there's more time, we can get involved and go and do what we want. And then the house will be demolished, and there's virtually no waste to be recovered.

In conclusion, the demolition contract only requires the demolisher to complete the job within the agreed time and cost without considering waste management. Therefore, this results in a contractual uncertainty for demolishers to which they must respond appropriately.

4.5.1.2 Meso-level uncertainties for QA

The demolishers' meso-level uncertainty is discussed in the following subsections, with interviewees identifying one meso-level uncertainty of demolishers for QA.

4.5.1.2.1 Management of demolisher's sub-contractors

As per the nature of building dismantling and on-site processing, demolishing organisations always employ sub-contractors for their work when it requires specialised expertise. Interviewee BD1 reported that, in most cases, demolishers use sub-contractors for labouring, asbestos testing and removal, soft stripping and transportation.

> We employ sub-contractors. The industry is full of sub-contractors because of the constraints within the industry: some days [have]work, some days [have] not, and some days you've got work for a week or two. So, there are many sub-contractors in the demolishing industry because they come and go. Some people are not reliable in coming to work. So yes, there are a lot of sub-contractors within our sector. (Interviewee BD1)

Interviewees confirmed that incorporating sub-contractors in their work benefits demolishers in many ways, as they can bring specialisation which is currently lacking to their organisation. However, on the other hand, managing many sub-contractors has become an epistemic uncertainty for demolishers. For instance, Interviewee BD4 explained this as follows:

> A major issue we encounter is that the understanding and importance of ensuring the quality of work is not the same with every sub-contractor. We cannot guarantee that they will comply with our policies, procedures and guidelines.

Interviewee BD4 further mentioned that, in most cases, sub-contractors engage in fewer interactions with staff of the employer company. As a result, at times, they are less committed to their work. Furthermore, Interviewee BD7 highlighted that he had encountered sub-contractors whose working style and approach did not blend with his company.

> So, I have had both good and bad experiences working with sub-contractors. Sometimes, they say, they are doing the work. And when I go and have a look [at] them, and then some just don't any sounds of it all, and I guess, smash everything. Cause time is money. (Interviewee BD7)

This indicates that, on the one hand, incorporating sub-contractors has become an opportunity for demolishers while, on the other hand, it has created epistemic uncertainty for the QA of demolishers in RLSCs.

4.5.1.3 Micro-level uncertainties for QA

From the analysis of the semi-structured interviews, the study found four micro-level uncertainties that demolishers encounter during the building dismantling and on-site processing phase for QA. The following subsections explain each of these uncertainties in detail.

4.5.1.3.1 'As-is' condition of the building

Interviewees highlighted that the difficulty in ascertaining the 'as-is' condition of the building is a micro-level uncertainty experienced by demolishers in RLSCs. Interviewee BD5 mentioned that demolishers are always assigned to dismantle buildings of which

they were unaware in advance. Thus, their job will be different from one project to the next. Consequently, at the beginning of every project, demolishers encounter uncertainty of what constitutes the 'as-is' condition of the building:

> We do not know how the building looks until we enter the site for a new project. It is quite a lot. So, we've just got to ascertain and see what is involved. Most unusual things arise after opening up the building during demolition, even after ascertaining. Therefore, the 'as-is' condition of the building is always uncertain for us. (Interviewee BD5)

Interviewee BD8 emphasised that the 'as-is' condition of the building can also be uncertain during the demolition process. Interviewee BD8 shared the following:

> Even though we made critical assessments of the building, some things will be just presumptions. In most cases, especially in old houses, asbestos appears from unexpected places, making our work more stressful. Also, sometimes we found buildings battered up to existing buildings, possibly raising the risk for demolition.

Therefore, the 'as-is' condition of the building is an epistemic uncertainty for which the demolishers should take appropriate IPMs before it becomes a disruption to their progress.

4.5.1.3.2 Management of contaminated/hazardous substances

Interviewees commented that managing contaminated/hazardous substances at the dismantling phase is an uncertainty for demolishers. Firstly, it become an uncertainty due to the difficulties in identifying some of these contaminated/hazardous substances before commencing dismantling. Interviewee BD4 acknowledged that many contaminated/hazardous substances could be present in a building, such as asbestos, rock wool, soil, lead-based materials, etc. Some substances could be easily recognisable, whereas others exist in hidden or invisible forms. For instance, Interviewee BD2 explained this as follows:

> In houses, friable and non-friable asbestos is mostly hidden and difficult to recognise at once. Rock wool is another dangerous product that everybody is not much concerned about. When you touch this, it's a little fine. But now, when you remove them, a lot of dust and invisible loose fibres get contaminated with air, which will not be good for your eyes, mouth, skin and especially lungs. Rockwool should be treated like friable asbestos when you remove it.

Secondly, even after contaminated/hazardous substances are identified, interviewees recognised that their management process is uncertain for demolishers. Interviewee BD2 highlighted that, instead of identifying contaminated/hazardous substances being the most uncertain task, their evacuation process has, in fact, the most uncertainty.

When contaminated/hazardous substances contained within building parts are damaged, dust and fibres can be released and become airborne. If anybody inhales this dust or these fibres, they could develop serious, life-threatening diseases. Therefore, building parts and even soil that is thought to contain contaminated/hazardous substances should not be disturbed, damaged or brought into contact with other uncontaminated materials throughout the entire process from removal to disposal. Given this point, Interviewee BD7 highlighted that:

> Removing hazardous substances like asbestos is [an] uncertainty that needs more experience, knowledge and procedures to deal with; otherwise, it will be a menace.

Therefore, managing contaminated/hazardous substances is a micro-level epistemic uncertainty for demolishers for which appropriate IPMs need to be employed.

4.5.1.3.3 Health and safety concerns of the demolisher

Interviewees confirmed that health and safety is an inevitable epistemic uncertainty experienced by demolishers during the building dismantling and on-site processing phase. According to them, this uncertainty could arise from operational and external factors. From an operational perspective, interviewees identified that the health and safety of the demolisher and their workers are uncertain due to hazardous and/or contaminated substances. Interviewee BD5 elucidated that inappropriate management of asbestos and other contaminated materials containing airborne fibres leads to adverse human health and safety conditions. This condition could be deadlier if workers do not use appropriate personal protective equipment (PPE) when handling these materials. Interviewee BD8 stated that a minimum level of threat exists if the contaminated and/or hazardous materials are evacuated in their original form without being damaged. If not, the danger may not be foreseeable as the fibres and dust released from the damaged contaminated components are not always visible to the naked eye.

Interviewees BD3, BD4, BD7 and SG2 emphasised that the entire demolition job is uncertain from the perspective of health and safety as workers on a dismantling site are exposed to many hazards, with these varying depending on the nature of the operation. Interviewee SG2 asserted that:

> Health and safety are important. We are generally receiving many accident cases on demolition sites. Most of them are related to the uncontrolled collapse of the structure or part of the structure due to poor planning of the demolition process. Usually, the demolition sites are small and confined; thus, the demolishers are exposed to more accidents.

At the same time, as clarified by Interviewee BD4:

> Basically, from the start of the job to the end, we make sure all the utilities are turned off. Electricity, gas and water have all been disconnected so people can work safely in the house. However, it is not always happening as planned. Exceptions would occur, and we'd have to be prepared for them. We can't presume whether the building could collapse during mechanical demolition or predict whether the bucket will hit workers. We can avoid them but cannot evade them.

From the external perspective, interviewees pointed out that demolition is uncertain for the health and safety of adjacent properties, traffic and the community. For instance, Interviewee BD1 revealed cases where mechanical demolition caused slight structural damage to neighbouring properties. Interviewee BD1 further mentioned that complaints from neighbours over disturbances due to noise and dust are very common in the demolition industry. Therefore, it is understandable that health and safety concerns are uncertain for demolishers; thus, appropriate IPMs should be undertaken in response to these concerns.

4.5.1.3.4 Workflow uncertainties of the demolisher

Interviewees confirmed that the entire workflow of the demolisher is uncertain due to the specific set of tasks carried out during the building dismantling and on-site processing phase in RLSCs. These workflow uncertainties are formed as a function of three constructs: (i) task variability, (ii) task interdependency and (iii) task analysability.

Interviewees reinforced the view that demolishers are vulnerable to several unanticipated events due to the task variability of dismantling jobs. Therefore, depending on the situation, demolishers should be able to adopt appropriate methods and approaches during their job. For instance, Interviewee BD9 mentioned that, in most cases, based on experience, demolishers could identify locations where asbestos would exist. However, in some circumstances, asbestos is found unexpectedly during mechanical demolition:

> We already know that asbestos is there. Therefore, before doing demolition, we just remove that part first. First, or during, depending on how it's set up. Sometimes you find it, and sometimes you don't know it's there. Anything weird that has asbestos; we don't touch it. Sometimes, we find asbestos in the footings formwork, which is not a common construction method, and this requires additional expertise and supervision to manage safely. (Interviewee BD9)

Interviewee BD6 pointed out that, in some cases, the building cannot be dismantled as planned due to unexpected constructions that were not recognised in the drawings or when visiting the site. Interviewee BD6 shared one of his experiences as follows:

> We had a residential building to demolish where all the window and door frames had been fixed using a special chemical anchoring procedure, and this was recognised when doing soft stripping. Due to this, the frames stuck firmly, making disassembly very hard and disrupting the progress of the job.

Interviewee BD7 added that sometimes after demolition, they come up with loads of unexpected waste that are difficult to manage at the site. Moreover, Interviewee BD2 mentioned that unpredicted adverse weather conditions are also a primitive cause for the poor quality of the demolisher's work:

> One is the weather. Today when it rained, we stopped the job; it cost us money. We have to wait till it dries. When it comes to the rain and other external factors, our destructed items get changed physically. Sometimes it becomes muddy; it becomes unable to work. You can't flatten; you can't push rubble out. Timber and stuff like [that] are not so much but more the dirt and stuff like that; it changes its factors. If it's very windy, that means a lot of dust going every way, so dust problems, so weather we can't control. Tipping rubbish with a sandy tipper in windy conditions is very dangerous. Then it will be difficult for us to sort it again and you can't work. (Interviewee BD2)

Interviewees repeatedly highlighted that this phase constitutes several interdependent sub-tasks; thus, the performance of each particular task depends upon other tasks. For instance, Interviewee BD5 elucidated that service disconnection, asbestos removal, soft stripping and mechanical demolition are sequential tasks in a dismantling job. If one task is disrupted, it will disturb the performance of all subsequent tasks. Therefore, workflow uncertainty is considered a concern during this phase due to this task interdependency.

As existing laws extensively regulate asbestos removal and management, a recognised known procedure to follow is established for performing these tasks. Interviewee BD3 voiced the criticism that, other than asbestos management, operations during this phase in SA are not regulated by legal instruments. Consequently, demolishers do not have an established procedure for many sub-tasks within their job, such as deconstruction, mechanical demolition and source separation. Thus, task analysability is uncertain for demolishers:

> Always on site, we separate, as I said, the concrete, brick, tin being metal, green waste being trees, and rubbish, or we have separate piles, so we load up both piles

> separately, don't mix it, because then it's cost prohibitive. So, we always separate those piles, start loading them individually and tip them off in the individual spots at the dump. There is no established process for this. (Interviewee BD3)

In summary, workflow uncertainties due to task variability, task interdependency and task analysability negatively affect QA during the building dismantling and on-site processing phase. Therefore, by undertaking appropriate IPMs, demolishers need to respond to their workflow uncertainties.

4.5.2 Epistemic uncertainties during the off-site waste processing phase

The epistemic uncertainties during the off-site waste processing phase, as identified by interviewees, are discussed in the following subsections. The current study found three macro-level, one meso-level and four micro-level uncertainties encountered for QA during this phase.

4.5.2.1 Macro-level uncertainties for QA

From analysis of the semi-structured interviews, the study found three macro-level uncertainties for QA encountered by waste processors during the off-site waste processing phase. The following subsections explain each of these uncertainties in detail.

4.5.2.1.1 Regulatory uncertainties

Interviewees emphasised that the extant regulations are not exclusively for waste management but to protect the environment and ensure workers' health and safety. Interviewee SG1 revealed that the *Environmental Protection Act 1993* (administered by EPA SA) and the *Work Health and Safety Act 2012* (administered by SafeWork SA) are the state legislative instruments that regulate CDW management in SA. The former legislative instrument's primary purpose is to protect the environment, while the latter is for workers' health, safety, and welfare. Therefore, no single regulatory instrument is found in SA exclusively for CDW management. Notably, this is an uncertainty common to both demolishers and waste processors. However, Interviewee SG2 mentioned that waste processors are more vulnerable as they appear as the focal node in RLSCs of DW. The existing regulations do not have the capability of providing how-to guidelines for waste processors, lacking workability when executed in real-world contexts:

> A lot of the regulations that encourage waste processing are quite wishy-washy. You'd like to have more detail from a regulation, which looks [at this] from our industry perspective. However, the existing regulations and codes of practice are

> generally written with a more comprehensive holistic approach to all industries. Thus, they become quite vague and not user-friendly. And you can see just looking around that it's not quite where it needs to be. I find that some regulations and requirements have been lost in translation. (Interviewee SG2)

Interviewee WP6 expressed the criticism that most experts who develop laws and regulations do not have a practical knowledge of waste management; thus, the feasibility of applying those regulatory requirements in the industry is problematic.

According to Interviewee SG3, even if a regulatory requirement existed to license MRFs in SA, as per the *Environment Protection Act 1993*, the EPA does not often monitor these facilities:

> We operate a risk-based system for monitoring our licensees. So, we have a minimum number of site visits we might have to do to a particular risk category of the operator on an annual basis. (Interviewee SG3)

On the same point, Interviewee SG1 emphasised that, in most cases, the EPA monitors the work of large-scale licensed MRFs as their complicated processes adversely affect the environment more than those of small and medium-scale waste processors. Therefore, in summary, the existing immature regulatory system in SA has failed to provide useful information for waste processors, thus creating an uncertain environment for QA.

4.5.2.1.2 Incentivising uncertainties

Interviewees expressed the view that one of the prime roles of state government agencies like GISA is to subsidise different industries to embrace the circular economy through developing infrastructure and introducing technologies to process and create new products from waste. Interviewee SG2 expressed the criticism that most subsidising and grant schemes offered in the past by GISA were only provided for projects targeting one or more waste streams from municipal, commercial and industrial sources such as plastics, paper and cardboard, glass, scrap metal, textiles and e-waste. Some grants, such as Recycling Infrastructure Grants, available to invest in equipment, technology and processes to recover, handle and process recyclable materials, were also not even available for waste processing in the construction industry.

Interviewee SG1 mentioned that, except for GISA, other state and local government agencies do not have the jurisdiction to provide funds or loans to promote RLSCs in the

construction industry. Even state government agencies like EPA are not actively educating waste processors in RLSCs of DW.

> As a regulator, [the] EPA doesn't. We will do that if we're asked to give a presentation on the Waste-derived Fill Standard. But we do our best to inform, but we're not an actual education facility with a regulator. (Interviewee SG1)

The state government agencies' poor engagement in leading and education discourages NGO involvement in the sector. Interviewee WP3 claimed that NGOs need government funding and initiation to engage in educational programmes and encourage industry compliance with existing regulations. With government support, many past promotional and educational programs were conducted by NGOs in SA, targeting other waste management streams but not specifically CDW management. Therefore, as with demolishers, waste processors encounter incentivising uncertainties to which they should respond appropriately.

4.5.2.1.3 Contractual uncertainties from FSC-downstream actors

Interviewees reinforced the view that most reprocessed products are utilised in civil and infrastructure projects; thus, in SA, the DIT is the principal end-user of reprocessed products. Through civil and infrastructure project contractors, the DIT provides information (via a materials supply contract) for waste processors on the quality requirements of reprocessed products. Interviewee WP9 mentioned that the DIT had developed a master specification that comprehensively describes all the materials tests needed to ensure final product quality. This has enabled the DIT to communicate the standard end-user requirements for the materials supplied across the construction industry. This master specification has separate sections, such as 'sustainability in design' and 'sustainability in construction', helping designers and contractors to identify key categories of materials for which the DIT allows virgin materials to be replaced with reprocessed materials. The DIT does not mandate the use of reprocessed materials but encourages project actors through this sustainability specification to optimise their use. However, waste processors need to produce these products based on the quality and performance requirements of virgin materials, as the DIT has not developed specifications exclusively for reprocessed products. Interviewee WP9 emphasised that comparing the quality of reprocessed products with the specifications of virgin materials is not feasible.

Interviewee WP10 criticised the master specification as being huge, complicated and not user-friendly. The DIT had not developed any guidelines nor was it conducting any training or information sessions to make it easy for suppliers to understand the specification, what is allowed currently and how to obtain approval for materials. Notably, these approaches have been successfully implemented in other jurisdictions such as Victoria. Given these points, separate specifications for reprocessed products need to be established to inform waste processors of the quality and performance criteria expected by end-users from these products.

4.5.2.2 Meso-level uncertainties for QA

Waste processors' one meso-level uncertainty for QA, as identified by interviewees, is discussed in the following subsection.

4.5.2.2.1 Mixed waste received from demolishers

Interviewees identified that mixed waste received from demolishers is an epistemic uncertainty experienced by waste processors in RLSCs. Interviewee WP3 highlighted that if any contaminated substances are mixed with the waste load and enter the MRF intentionally or unintentionally, the waste processor's entire business would be at risk:

> Oh, they're crucial. But that's more about what happens on site. What we produce is a direct reflection of the materials we receive. So, if we get poor-quality materials, our product will be poor quality; it's not a magic store that we run. So, policy and procedure are crucial, but if materials are handled on site correctly at the demolition point, we will get quality materials into our gate. Then we can make a quality product out of it. (Interviewee WP3)

Interviewee WP1 mentioned that his organisation only accepts concrete, plastic, metal and some green waste that can be easily classified. However, in some cases, they also receive contaminated mixed waste which is not accepted and is redirected to a licensed landfill facility. Interviewee WP7 emphasised that mixed waste loads contain hazardous substances such as asbestos, oxidising materials and lead-based materials that make other materials in waste loads hazardous. Interviewee WP7 further revealed that some items, such as gas bottles and glass items, if they have not been removed from the waste load, could even damage the waste reprocessing facility's plant and machinery.

Interviewee WP4 asserted that small and medium-scale demolishers take mixed waste to the MRFs more than is the case with large-scale ones. Interviewee WP4 explained this difference in detail as follows:

> The big demolition companies like … who are doing either hospital or Footy Park stadium, you know, really big jobs, there's lots of scrutiny and supervision over their work. So, it's quite a lot of work done upfront. And on the other hand, when the load is probably from owner-operators, knocking down a housing trust home, or something like that, they are the people who try to do the right thing. And then some people may be a bit less outside the cowboys, trying to hide stuff under the load and so on. So, we've been doing this for a long time and know who's genuine and who's not.

Interviewee WP4 also highlighted that if they recognise a mixed waste load, the remedial side is easier with large-scale demolishers who act more professionally than small and medium-scale demolishers.

4.5.2.3 Micro-level uncertainties for QA

From analysis of the semi-structured interviews, the study found four micro-level uncertainties that waste processors encounter for QA during the off-site waste processing phase. The following subsections explain each of these uncertainties in detail.

4.5.2.3.1 Product description complexities

Most interviewees confirmed that waste processors encounter uncertainty in terms of understanding end-user requirements of reprocessed products. Interviewees WP2, WP5 and WP6 highlighted that customer dissatisfaction over reprocessed products is a significant barrier to the endurance of RLSCs in the construction industry. Interviewee WP5 elucidated that some end-users negatively perceived the quality of reprocessed products even without using them. Moreover, another cluster of end-users had practical experience of quality issues in reprocessed products during real-context applications.

> So, in Adelaide, we sell 600,000 tons of recycled material a year. So, we sell a lot of it, and we have done it for the past 20 years. However, when you approach a new customer, there's a reluctance to buy reprocessed products due to their perception of poor quality. On the other hand, unfortunately, operators within the industry don't follow all the protocols and quality procedures. And so that tends to tarnish reprocessed products. (Interviewee WP5)

Interviewee WP8 expressed the criticism that the functional and technical performances of reprocessed products produced by some waste processors were not fulfilling end-user requirements. Therefore, the construction industry generally does not have a good reputation for the quality of reprocessed products.

It was also observed that quality was not the only criterion considered by end-users when using reprocessed products. Interviewees WP2, WP5 and WP9 revealed that end-

users, in some circumstances, demand cheaper products over quality products. Interviewee WP9 highlighted that waste processors face the significant challenge of producing more affordable products as the production cost for these materials is considerably higher than for virgin materials. Therefore, most end-users are not enthusiastic about the use of reprocessed products in place of virgin materials:

> Of course, recycled products are a little more expensive, mainly because of the labour-intensive production process. Also, it has huge processing involved with waste taking, handling, sorting, processing and marketing. You know, all these are pretty expensive. (Interviewee WP9)

With all these challenges, Interviewee WP4 highlighted that waste processors do not have an extensive awareness of customer expectations for reprocessed products. Consequently, a significant mismatch exists between the demand and supply of reprocessed products. The unavailability of standard specifications for reprocessed products compounds waste processors' uncertainty in understanding end-user requirements for these products. However, complying with standard specifications would not completely avoid the product description complexities faced by the waste processor. Instead, waste processors should interact with end-users to understand their expected technical, design and functional requirements of reprocessed products.

4.5.2.3.2 Human errors

Interviewees revealed that successful waste processing work requires significant human resources, even if tools, plants and equipment are involved. Interviewee WP1 affirmed that around 75%–80% of waste processing is manual; thus, waste processing organisations put extreme efforts into their staff's understanding of the importance of QA. However, Interviewees WP1, WP4 and WP5 reinforced the point that waste processing organisations are highly vulnerable to human errors despite greater efforts being made to make the process perfect. In particular, Interviewee WP4 stated:

> It's mainly humans involved, so people make mistakes; we all make mistakes. Sometimes, things get through, not very often, but we also, like I said, with any manual processes, an area where it can be, it can be a mistake.

Interviewee WP5 identified that human errors during off-site waste processing primarily arise due to workers' forgetfulness, inattention, negligence and carelessness. All these factors could be categorised as human-related factors. Interviewee WP5 further revealed that it is difficult to avoid human mistakes which evolve from factors due to the nature of humankind. Interviewee WP8 also emphasised that the nature of the job further

compounds human errors during waste processing. For instance, workers who repeat the same waste-picking movement for long hours quickly become exhausted, making many mistakes in their job. Interviewees WP3 and WP4 pointed out that organisational factors also augment human errors. Interviewee WP3 explained that incorrect procedures and knowledge, miscommunication and less supervision could lead to human errors during this phase; however, these factors are manageable.

4.5.2.3.3 Health and safety concerns of the waste processor

Several interviewees highlighted that ensuring workers' health and safety during waste processing is another area of uncertainty. Accordingly, workers in the waste processing facility are subject to the following three types of dangers during off-site waste processing due to:

1 Handling of vehicles, plants and equipment
2 Handling of contaminated/hazardous substances in mixed waste
3 Unsafe working environment.

Interviewee WP4 pointed out that most human injuries during waste processing occur due to workers' exposure to active plants and equipment. It was found that new workers were mostly subject to these accidents as they tried to work hard at the beginning to impress their superiors. Interviewee WP2 shared some examples of accidents that he observed during off-site waste processing as follows:

> There is a human risk. We have many heavy machines operating outside and people walking around, so safety is a huge focus because we are not all sitting at desks. There is quite a good opportunity for people to get hurt when using heavy machines and crushers. Another time, a piece of the plant fell off, and the person thought it was metal coming through the product. So that is an absolute disaster, but it happened, and his back got hurt and he recovered after a couple of weeks.

Even though MRFs do not accept contaminated/hazardous substances, they may receive these substances in other waste streams. For this reason, workers face unexpected risks, especially those at an MRF engaging in waste picking. Interviewee WP1 explained the uncertainty of workers' health and safety due to the presence of contaminated/hazardous substances.

> There are risks of silica, rock wool and asbestos and things like that. For instance, if rock wool is present, we cannot even recognise it; we cannot even touch it, but it is dangerous to everybody in the plant if exposed to air. Therefore, we make efforts not to enter any of these harmful materials into the plant, but there are some unexpected situations that we cannot avoid totally.

Interviewees also mentioned that inappropriate working environments at MRFs threaten workers' health and safety. Interviewee WP6 stated that unsafe walkways around the plant, prolonged repetitive working arrangements and incorrect usage of PPE are potential sources of accidents ranging from mild injuries to fatal incidents. Interviewee WP4 emphasised that noise, dust and fumes generated from waste processing also endanger the health and safety of workers if they are not protected through using appropriate personal protective equipment (PPE). At the same time, Interviewee WP4 stated that, if considerably large amounts of noise, dust and fumes are emitted from the plant, the health and safety of those in the neighbourhood are also threatened. Therefore, health and safety are always uncertain for waste processors as they are unavoidable but, by undertaking appropriate IPMs, they can be properly managed.

4.5.2.3.4 Workflow uncertainties of the waste processor

Off-site waste processing constitutes a series of variable, interdependent and less analysable tasks. Due to these intrinsic characteristics, interviewees affirmed that the waste processing workflow is uncertain; thus, appropriate responses should be undertaken to achieve the expected level of performance.

Several interviewees highlighted various examples in which waste processors encounter unanticipated events during off-site waste processing. For instance, Interviewee WP7 pointed out that sorting and segregating before reprocessing, at times, become uncertain as materials hidden in the waste go through to conveyor belts. Even if materials, such as asbestos and rock wool, are not permitted to enter the MRF, the possibility exists that they may enter the facility due to incorrect monitoring at the drop-off station. In the same way, circumstances may occur in which some large-sized rocks and bricks which cannot be easily crushed for further reprocessing may enter the plant:

> The main uncertainty is hidden materials that we are not informed or aware of. For instance, we are vigilant about asbestos, chemicals, hazardous chemicals and oils because if some happen to slip through our system and go into our products, that would be the end of our business. Also, sometimes hidden bricks and rocks falling off the conveyors would damage our equipment. (Interviewee WP7)

Even if waste processors comply with the specifications, secondary products that fail to adhere to the specifications could be produced. For instance, Interviewee WP2 revealed that, a few years ago, the trommel screens at his organisation's MRF produced an unexpected byproduct of the fines. At that time, they did not have information regarding how the byproduct could be treated.

As another example of task variability, interviewees mentioned that it is difficult for an MRF to predict the incoming and outgoing amounts of materials and products. Interviewee WP4 revealed that, on some days, an unmanageable amount of waste was received by the MRF while, on other days, little waste came into the facility. Depending on the quantity of materials accepted into the MRF, production will vary, at times, making it difficult to meet market demand. Interviewee WP4 explained this in detail as follows:

> Another risk is that we could have many products coming in or sometimes none. The sales team came in because we got nothing to sell if nothing came in. So, someone has to keep following [up]. They will be stockpiled if we've got plenty of materials coming in and not selling any rubble. When it gets bigger and bigger, [the] EPA is onto us. Because we only have a licence to store a certain amount.

Interviewees also highlighted that the entire waste processing includes interdependent sub-tasks that eventually compound workflow uncertainty. For instance, Interviewee WP6 explained the interdependent workflow of off-site waste processing as follows:

> We have a comprehensive recycling process for construction and demolition waste. In the first stage, all the material passes through a screening plant that runs over to remove the sub-15 mm fraction of the waste stream. This consists mainly of soil and smaller fragments of concrete and stone. The material is then screened again to remove the sub-7 mm fraction, and the remaining soil is tested and reutilised as clean fill.

Interviewee WP6 emphasised that, as this process is linked to interdependent sub-stages, the entire process will be disrupted if any issue arises. As this process is more mechanical, the whole batch of products must be removed if any contaminated substance enters the plant. Therefore, task interdependency is a cause of workflow uncertainties during this phase.

A known procedure based on the regulatory instruments specifies the steps that waste processors must follow when managing asbestos and other contaminated substances. For instance, Interviewee WP2 highlighted that, in accordance with the EPA guidelines, even if inert materials could be kept as stockpiles on site, asbestos and other combustible materials should be quickly disposed of at a suitable facility. However, Interviewee WP2 reported that no procedure had been established for any task, other than asbestos management, in this phase. Therefore, low task analysability is a major concern during off-site waste processing in RLSCs of DW.

4.6 Information Processing Mechanisms (IPMs) for QA in RLSCs of DW

The above section identified and explained 16 epistemic uncertainties that lead to IPNs for QA in RLSCs of DW. This section discusses 15 IPMs that internal stakeholders could undertake in response to the epistemic uncertainties for QA. These IPMs are classified as (i) IPMs of demolishers and waste processors; (ii) IPMs exclusive to demolishers; and (iii) IPMs exclusive to waste processors, as shown in Table 4.4. The following subsections explain each of these IPMs in detail.

4.6.1 IPMs of both demolishers and waste processors

Interviewees identified eight IPMs that demolishers and waste processors undertake in response to IPNs arising from epistemic uncertainties. These are presented in Table 4.4 and explained in detail in the following subsections.

Table 4.4. Summary of information processing mechanisms (IPMs)

Internal Stakeholder Category	Information Processing Mechanism (IPM)	Description
Demolishers and waste processors	Rules and programs	Rules and programs encompass internal policies, procedures, guidelines and frameworks that provide internal stakeholders with a fixed and objective knowledge base.
	Planning and goal setting	Establishing plans and setting goals leave internal stakeholders to decide which behaviours to enact.
	Business partnering	Develop strategic relationships with business partners to achieve competitive advantage while sharing the lack of resources and competencies.
	Forming contracts	Form a legitimate formal document between parties mentioning what parties have agreed to do and have not agreed to do within the scope of the job.
	Group meetings	Conduct face-to-face group meetings to coordinate work, discuss issues and share opinions, perceptions and judgments.
	Hierarchical referral	Refer infrequent problems up the hierarchy to find solutions.
	Incorporation of self-contained groups	Form independent groups with all the resources and capabilities to perform the tasks.
	Investment in technologies	Augment the IPCs by embracing various man–machine combined assistance.
	Creation of slack resources	Increase planning targets or reduce performance level to reduce the number of exceptions.
Demolisher	Collection of building documents and asbestos registers	Collect ‘as-built’ drawings and asbestos registers to understand the details of the ‘as-is’ condition of the building.
	Site visits/pre-demolition audits	Site visits/pre-demolition audits allow demolishers to assess the ‘as-is’ condition of the building while evaluating non-hazardous and hazardous waste that needs to be removed from the building.
	Performance evaluation of sub-contractors	A mechanism that enables an understanding of what sub-contractors are performing to produce quality output.

Waste processor	Creation of integrator roles	Assign an organisational role to a boundary-spanning activity.
	Waste acceptance criteria/gate fees	The criteria used to accept the waste into the MRF, and the corresponding gate fees advocating that waste processors avoid receiving mixed waste from demolishers.
	Creation of special reports	Gather feedback from end-users about the quality of reprocessed products, synthesise this feedback and undertake appropriate measures for any identified issue.

4.6.1.1 Rules and programs

Interviewees identified that demolishers and waste processors had developed internal policies, procedures, guidelines and frameworks (i.e., rules and programs) to guide their work in response to epistemic uncertainties. Interviewee SG1 introduced these policies and procedures as the 'backbone' of organisations in RLSCs, stipulating the standard rules and guidelines that internal stakeholders should follow to deliver quality output. In particular, Interviewee BD3 expressed the following:

> SafeWork SA and the EPA heavily govern our industries. Whether that's right or wrong, I don't know. They can be overzealous there; I think they can be overpowering, and sometimes, the theory is good. It doesn't quite work out that way when you put it into practical terms. Sometimes, experience outweighs the practical side of things if you're doing it properly, safely and professionally. Therefore, based on my experience, I have developed all my policies, inductions, and that sort of stuff internally.

This statement emphasises that internal stakeholders in RLSCs (i.e., demolishers and waste processors), primarily in response to regulatory uncertainties, develop all the policies and procedures within their organisations without relying on regulatory bodies. Interviewee WP3 raised the importance of involving operational-level workers when developing these company-based policies and procedures. This essentially does not happen when regulatory bodies develop regulations and codes of practice:

> One of the things I found was those regulations and their requirements do not apply to our industry. Therefore, I learned the importance of being consult[at]ive when developing internal policies. So, all of our policies or procedures [are developed], and then I'll take [them] to the staff, and I'll say, this is just me sitting in the office, writing down how I think it is, you guys are out there doing the job, get your red pen out, go on it and let me know what changes need to be made. And then they bring it back, and then I'll change it, or I'll say, hang on there, I don't think that's right. Like we get to a point where we've got a finished product that meets the requirements, signing for the quality, safety, whatever it might be. (Interviewee WP3)

Interviewees highlighted that most demolishers and waste processors in SA have obtained third-party accreditation for their organisations which they have used to develop their in-house policies and procedures. For instance, Interviewee WP7 stated:

> We use a third-party management system certified by the Civil Contractors Federation. This certification ensures industry standards based on ISO 9001, AS/NZS and ISO14001. Furthermore, we maintain quality, health & safety, and environmental sustainability policies. So, there are no other regulations and policies that we need to meet.

These policies outline the organisation's holistic view of how it is going to assure quality, health and safety, and environmental protection. Each of these policies constitutes work procedures, instructions and manuals for every major activity they perform. For instance, Interviewee BD5 revealed the three codes of practice in SA related to asbestos management: 'How to Manage Work Health and Safety Risks, Code of Practice 2011', 'How to Safely Remove Asbestos, Code of Practice 2011' and 'How to Manage and Control Asbestos in the Workplace, Code of Practice 2011'. Even if these codes of practice explain in detail how to manage asbestos safely, they are complicated, lengthy and not easy to scrutinise. Therefore, as part of his organisation's occupational health and safety policy, safe operating procedures, work health and safety instructions and quality work instructions, including a summary of the most important measures to follow when managing asbestos, have been developed to inform workers on site:

> I have developed safe operating procedures for the removal, collection, storage, transportation and disposal of asbestos waste, developing these aims to inform anyone involved or carrying out asbestos removal work on the safe handling and suitable control measures described in SafeWork SA's code of practices. (Interviewee BD5)

However, a few interviewees believed that the policies were merely statements. Interviewee WP5 stressed that gaining third-party accreditation is an unnecessary cost for a business as it does not offer substantial benefits except for promoting the brand name. However, Interviewee WP5 pointed out that his organisation still had policies and procedures, even if it was not guided by third-party accreditation. In contrast, Interviewee BD8 stated that, rather than promoting the brand name, the policies and procedures developed with third-party accreditation were useful in creating 'self-discipline' in his organisation, as they informed how the internal processes should be organised to produce quality output.

> I think there are two things. On the one hand, it's good for the sales and marketing team. It implies that the company is legitimate and at a certain standard. And that works from a marketing point of view with many tenders for governments and first builders. To me, the bigger thing is it's a form of self-discipline. So, it keeps you honest with all the policies and procedures. How are you doing that? Is that being

> calibrated? Are you meeting that? Are you doing the training? Are you consulting? Do you have a management overview? All these parts of the standard policies keep you honest; make sure that you're not just going through the errors. You don't forget stuff and don't take things for granted. And to me, that's the bigger part of it. It's like a massive checklist. It's about accountability and a higher standard. And so sometimes you don't get it. So sometimes, you fail to reach that. So, what are we going to do to fix it? (Interviewee BD1)

Organisational policies and procedures developed based on existing laws and regulations provide the rules and programs to predict job-related situations. These rules and programs establish a standard and self-disciplinary environment for demolishers and waste processors to avoid epistemic uncertainties sourced from both external and internal organisational environments.

4.6.1.2 Planning and goal setting

Planning and goal setting comprise an IPM adopted by internal stakeholders in response to epistemic uncertainties for QA. The interview analysis findings revealed that demolishers and waste processors both undertake this mechanism; however, their methods of implementing it are different.

Interviewee BD7 revealed that demolishers undertake extensive planning to complete a dismantling job within the allocated time and budget for two reasons. On the one hand, they plan the job as they cannot go against the conditions the contractor/developer/client sets in contracts. On the other hand, they always try to perform efficiently and effectively to maintain a good relationship with contractors/developers/clients to receive more jobs in the future. Therefore, even if demolition contracts do not provide sufficient information and requirements to encourage waste recovery, demolishers plan the job to achieve the set budgetary and time goals:

> The developers just want the building down. It's up to us once we get the job; it's up to us to manage the site and do the job. So, we've got a process that we follow. So, we've got to plan it within the process of what we do. And we do it the way we do because we know how to do it safely and professionally. (Interviewee BD7)

Interviewee BD1 indicated that demolishers develop a 'demolition management plan' for each job. A typical demolition management plan provides the necessary methodologies and procedures for dismantling buildings in the assigned project. This plan includes important information about the scope of the work, site access, site organisation, demolition methodologies, recycling, transportation and tracking, safety and environmental risk control, asbestos air monitoring, noise, vibration and dust

control procedures, and work permits. Interviewee BD7 mentioned that the demolisher also prepares an asbestos removal control plan, safe work method statement, safety checklist, environmental plan and resource allocation plan for each demolition job. Interviewee BD7 further added that:

> The challenge is to do the job safely and correctly as to what the client or customer wants and ensure there's no danger to our people when we do it. And then make sure that we've done a satisfactory job that the person is happy with at the end of the day so that they can then build or sell a block of land and do what they've got to do. So, we've got to make sure by planning to use our expertise to do the job that's 100% right for them.

From the waste processors' perspective, internal plans and goals are developed to produce quality reprocessed products in compliance with the in-house specifications. For instance, Interviewee WP4 asserted that waste processors usually develop a product quality management plan that outlines the approaches used in manufacturing and supplying each reprocessed product to the industry. All the quality control (QC) and production procedures specified in these product quality management plans are based on the organisation's quality policy, procedures and guidelines (i.e., rules and programs). Interviewee WP2 revealed that waste processors also develop in-house specifications for their reprocessed products as part of the product quality management plan:

> We have obtained performance-based mix design certification from the DIT for its 20 mm Class 1 recycled material at Wingfield. The certification was achieved through comprehensive testing carried out by both the DIT and the company's independent National Association of Testing Authorities (NATA)-approved laboratory within the DTI R15 specifications. (Interviewee WP2)

Interviewee SG1 stated that when a waste processor is about to produce a new product, the EPA undertakes regulatory efforts to assess the product and to grant approval for the product specification developed by the waste processor:

> For example, ... has developed a specification for trommel fines from the trommel process as an alternative daily cover at the landfill sites, so that required a specification, and ... went out and did all the technical work. And then that got approved by the EPA, but it has very restricted use. (Interviewee SG1)

In summary, 'planning and goal setting' is an IPM that both demolishers and waste processors have undertaken primarily in response to contractual uncertainties from forward supply chain (FSC)-upstream and downstream actors.

4.6.1.3 Business partnering

Interviewees identified ‘business partnering’ as an IPM that demolishers and waste processors undertake to avoid the epistemic uncertainties for QA in RLSCs of DW. Interviewee WP2 highlighted that waste processing is rapidly changing with new technologies. Therefore, government financing is a significant impetus for them to invest in these technologies. However, due to the limited government financing options, internal stakeholders in RLSCs build partnerships with several waste management organisations with different specialisations. For example, Interviewee WP2 revealed:

> We have partnerships for different projects with ... All of us were bringing cash into the projects, and thereby, we could raise more capital to grow our business. Also, each of these companies has a specialisation that we lack. Thus, we were able to expand our business using their know-how, technologies and experience.

Interviewee WP2 further pointed out that their partnership programs resulted in a huge amount of waste recovery and a significant diversion of waste from landfill sites. Therefore, the business partnership is a mechanism used by internal stakeholders in RLSCs to overcome uncertainties, and especially incentivising uncertainties. However, Interviewee BD5 claimed that business partnering has only been a feasible solution for large-scale demolishers and waste processors but not for small and medium-scale organisations.

4.6.1.4 Forming contracts

Interviewees revealed that ‘forming contracts’ is an IPM that demolishers and waste processors employ in response to epistemic uncertainties, especially those at the meso level. For instance, Interviewee WP1 revealed that waste processors form contracts to ensure they are not receiving mixed waste from demolishers:

> In the past, we had a contract with … So, in the city, there was the old Harris Scarfe building. That building was demolished a few years ago now. As per the contract, all that demolition material was brought to us, and we processed that material into rubble, which went back to the site as the base for the new buildings. So, we do that so people can provide a full-circle story for their project. (Interviewee WP1)

Interviewee WP1 asserted that they yielded 80% waste recovery from this project, which is a significant rate for a complex and outdated building dismantling project. By forming a contract, waste processors inform demolishers about the sort of waste materials they will accept for their MRF and their assigned gate fees. The gate fees assigned in this type of contract are always lower than the general gate fees, creating a

win-win situation for demolishers and waste processors. However, it is important to highlight that only large-scale waste processors and demolishers adopt this mechanism; thus, it is not common in the industry.

Demolishers also form contracts, especially when they involve sub-contractors in their work. Interviewee BD9 mentioned that, as in any form of sub-contracting work in the construction industry, demolishers make contracts for the demolition-related works that they will sub-contract. Interviewee BD4 articulated that a sub-contract provides proof of what has been agreed upon; thus, it helps prevent disputes between parties. The contract acknowledges both parties and the activities that sub-contractors are entitled to perform during the job. Therefore, forming a contract provides assurance that sub-contractors will perform better to ensure job quality.

4.6.1.5 Group meetings

Interviewees identified 'group meetings' as an IPM for QA in RLSCs of DW. Interviewee BD2 highlighted that they frequently have meetings (i.e., direct meetings) at dismantling sites incorporating all in-house employees and sub-contractors. Generally, meetings are scheduled weekly to discuss the project's progress and to ensure they are working properly to yield a quality output while considering health and safety concerns on the site. From the perspective of waste processors, Interviewee WP7 expressed that, in addition to toolbox and quality meetings, they have fortnightly management meetings to discuss the issues and progress of different departments in the organisation:

> We have a lot of meetings, and I find it interesting to see what the others are working on and some of the projects [where] you've overlapped with them. And [if] you['ve] already got a fairly good understanding of all the things, you had no idea why [they] were happening because they didn't relate to you. And I think it's really good to know what your colleagues are working on. There's a lot of overlap in my role, so I tend to have a fair idea of what's going on. So yeah, I think people work better when they understand and see where they fit into the jigsaw, their role scope, and what their colleagues are doing. So, the more we can understand what our colleagues are doing, where we fit in, and what we can do to improve things, the more it will work. (Interviewee WP7)

These direct meetings enable employees to exchange their opinions, perceptions and judgments. The strength of these meetings is their ability to overcome uncertainties while building understanding and agreement. In addition, they allow employees to

coordinate with each other, which helps them avoid disruptions in their interdependent tasks.

4.6.1.6 Hierarchical referral

Interviewees highlighted that 'hierarchical referral' is another IPM undertaken by demolishers and waste processors in response to their epistemic uncertainties, especially those at the micro level. For instance, Interviewee BD4 revealed that, after referring to the drawings and asbestos registers (if available) and after a site visit and pre-demolition audit, workers in a demolishing organisation develop a report to their senior management referring to all the issues they found in the project. This report helps senior managers to negotiate with the contractor/developer/client regarding the work price which is likely to depend on the criticality of these existing issues. Moreover, senior managers provide their insightful responses to these issues for operational-level workers to consider when carrying out dismantling operations on the site.

Interviewee BD9 stated that senior management's continuous supervision of workers' performance is also essential to ensure that they are working in a safe environment. Workers should always be able to easily reach senior managers whenever they need guidance and advice to tackle situations that threaten their health and safety.

> I'm responsible for the safety of the guys working; I'm responsible for managing the asbestos removals, so I'm o -site with those there to make sure it's correctly removed and whether they wear the correct PPE. So, I advise them when they need me. (Interviewee BD9)

On the same point, Interviewee WP8 revealed that his waste processing organisation follows an open-door policy where all managers welcome consultation with employees whenever they encounter any issue in the plant. In addition, these managers often visit the plant and engage with workers to understand the operational problems that need to be rectified during process improvements:

> We usually run the company with an open-door policy and teamwork on site. I go to the site a fair bit; obviously, COVID made it harder. I wasn't allowed to go outside for a bit. But we tend to have an open-door policy. So, if somebody wants to ask a question, we'll answer it where possible. And we have had the staff for a long time; good staff know the owners. And it's still got that informal communication level. And then we also have more formal things, but if there are any major change to operations, we're obligated to consult with the workers. (Interviewee WP8)

Therefore, from all these statements, it is evident that 'hierarchy referral' is an important IPM that uses the chain of command to avoid most epistemic uncertainties encountered for QA by both demolishers and waste processors.

4.6.1.7 Incorporation of self-contained groups

Interviewees identified that the 'incorporation of self-contained groups' is an IPM for QA in RLSCs of DW. Both demolishing and waste processing organisations always try to form worker groups, including all the resources and expertise needed to perform the assigned tasks. For instance, Interviewee BD5 revealed that demolishers employ specialised laboratory services to test a building's contaminated/hazardous substances if the information on the asbestos register is unreliable. These accredited laboratory services have a team of licensed assessors who are experts in testing and providing clearance reports with regulatory bodies accepting the need for a rapid turnaround:

> Sometimes we come across stuff that the asbestos register hasn't picked up. It's hidden. You can't see it. We can tell if it's not, but we get samples of areas that we think are tested under a microscope by the … company that we use to see if there are contaminated crystallites in fibres. (Interviewee BD5)

In addition, demolishers also employ a separate self-contained team to manage contaminated/hazardous substances on the site. Interviewee BD1 clarified that, as per regulatory requirements, workers involved in removing all the asbestos-containing materials should be licensed under SafeWork SA. As part of this licensing process, workers undergo a competency development program that enables them to be experts in their field. Demolishers only employ licensed and experienced workers to manage asbestos in dismantling projects; thus, they do not need any external support or resources (i.e., they are self contained):

> We have our trained group of people for managing hazardous materials. We usually have training every six months. We assess the building or the structure; whatever we're looking at, we assess that. And we make sure that we've identified that there are hazardous materials in the particular building. (Interviewee BD1)

Interviewees also emphasised the incorporation of a self-contained team of workers to avoid epistemic uncertainties related to health and safety. Interviewee WP5 mentioned that developing rules, programs and plans is insufficient on its own and it would not be practicable if frontline workers were unaware of health and safety concerns and had no idea how to effectively face them. Therefore, frequent training, competency development and licensing are imperative for workers to safely engage in their job:

> We have a …, it is an Adelaide-based company. So, I have safety systems and training; internal training is built around that. So, we'll have a skills matrix, what you need for this goal, and how it will happen. So, it's an internal module. What we've tried to do is provide a pathway for them. So, we'll get the tickets once that ticket [is issued], so we … know [about it], like Bobcat licence, forklift licence, first aid, White Card and asbestos handling. (Interviewee WP5)

With these statements, it is evident that the 'incorporation of self-contained groups' is another IPM that demolishers and waste processors could employ in response to their micro-level uncertainties.

4.6.1.8 Investment in technologies

Interviewees confirmed that 'investment in technologies' supports information processing during the task performance of both demolisher and waste processor. For instance, Interviewees BD2 and BD6 highlighted those technologies, such as air monitoring, ensure that dismantling sites are safe and free from asbestos. This, in turn, helps demolishers to confront uncertainties, such as managing contaminated/hazardous substances and health and safety concerns. Interviewee BD6 explained in detail the importance to a demolisher of air monitoring:

> We have air monitoring to pick up airborne fibres when removing the asbestos. If the readings are too high, we haven't been removing them properly. We need to remove them slowly and try to minimise breakages in removing asbestos. So that creates less dust and fewer fibres, but that's if you get a higher reading.

Interviewees identified that some demolishers and waste processors are using near-infrared (NIR) spectrometers to detect the presence of asbestos. Interviewee BD7 revealed that a spectrometer is important for a demolisher to accurately recognise where asbestos is present in the building to be dismantled. Moreover, Interviewee WP3 mentioned that waste processors need this spectrometer to confirm that asbestos is not present in waste streams accepted at the weighbridge.

Interviewees pointed out some technologies that MRFs could use for sorting different types of waste. For example, optical sorters (Interviewee WP1) and online analysers (Interviewee WP8) are a few of the newest technologies employed by waste processors to enhance the accuracy of waste sorting and segregation in their plants. In particular, Interviewee WP8 extensively explained how an online analyser worked in response to his organisation's micro-level uncertainties:

> It's an online analyser which we put into our plant. It bounces reflected light off of things and picks [them] up. We're looking for non-ferrous metals. Of course, the

> ferrous metals are picked up by the magnet. So, we are implementing [the] online analyser. Things out on the conveyor belt and comes back and pick[s] up anything, a little sidearm comes up, and it runs off into a skip. Someone can look at it, take it out, and go back to reprocess through the plant. So yeah, that is a technical solution.

Considering all these statements, it can be concluded that 'investment in technologies' is an IPM that demolishers and waste processors undertake, especially in response to their micro-level uncertainties.

4.6.1.9 Creation of slack resources

Interviewees confirmed that the 'creation of slack resources' is an IPM for QA in RLSCs of DW. A few examples were given of circumstances in which demolishers and waste processors had to create slack resources in response to epistemic uncertainties. Interviewee BD3 stated that if they found a demolition job was likely to threaten health and safety, the circumstances could be such that demolishers would reduce the progress of the work even if the contractor/developer/client faced a strict time constraint:

> If we think it's risky, we're going to pull the wall down; if it's a particularly high wall, if it's a boundary wall, we're going to bring that down by hand. So, with or without the machine, bring it down by hand, so we can control the wall, so the wall doesn't fall over and cause some damage to property or people.

Dismantling is always vulnerable to unexpected dangers. Therefore, Interviewee BD2 revealed that they keep a substantial amount of time between tasks when planning a new dismantling project to deal with unforeseen circumstances. Interviewee BD2 further mentioned that they add a considerable percentage of contingency to the total budget to cover the extra costs that might be incurred due to unexpected conditions.

Interviewee WP5 indicated that, as task interdependency is high in waste processing, a waste processor is needed to allocate sufficient space to stock waste either on or off the MRF. If not, the waste processor could experience difficulty managing the waste inflow to the MRF if any disruption to the production process occurred due to either health and safety concerns or any other serious concern:

> Just in stockpiles, of course. We do have a special kind of procedure to manage the stockpiles. Yes, we separate it by the customer, so we have a special open area where you sign for different customers. But it doesn't stay there much; the process line is very quick so that you can process; in most cases, you process the daily material each day. And we won't keep it longer unless there is a serious disruption. (Interviewee WP5)

In conclusion, demolishers and waste processors create slack resources to increase their planning targets in response to the micro-level uncertainties that they encounter.

4.6.2 IPMs exclusive to demolishers

Interviewees identified three IPMs exclusively undertaken by demolishers in response to IPNs arising from epistemic uncertainties. The following subsections explain each of them in detail.

4.6.2.1 Collection of building documents and asbestos registers

Interviewees identified that the collection of building documents and asbestos registers is an appropriate IPM that responds to demolishers' micro-level uncertainties. Interviewee BD5 indicated that if they have been provided with the 'as-built' drawings and the asbestos register, they can ascertain much of the important information about the 'as-is' condition of the building.

> The only information we ask from developers is if they've got 'as-built' drawings of the building. That shows us how it was built, the structural integrity and how deep the footings are, and if there's an asbestos register, and then the rest we can work out ourselves.

Interviewee BD2 highlighted that referring to 'as built' drawings and asbestos registers is also important for effectively managing contaminated/hazardous substances. Demolishers never proceed with dismantling without accurately recognising where contaminated/hazardous substances are present in a building. Interviewee BD7 pointed out that the collection and thorough examination of drawings and asbestos registers also recognised the health and safety risks of the job before its commencement:

> I could know the boundaries we're knocking on because they have indicated it on drawings. So, there might be a dotted line saying, 'Remove that fence, keep that fence', or there might be a private house next door, so you can't take the fence down; you have to be more careful. So, we have provided the asbestos register and demolished the house safely. (Interviewee BD7)

Interviewee BD1 stated that demolishers will develop conceptual drawings by including the information they need so they can understand the 'as-is' condition of the building if they are not provided with 'as-built' drawings. Interviewee BD2 mentioned that almost all commercial buildings in SA have asbestos registers unlike most residential buildings. If an asbestos register is unavailable, the demolisher will ask an asbestos specialist consultant to prepare an up-to-date one before commencing the job.

With all these statements, it is evident that the collection of building documents and the asbestos register is an important IPM for demolishers, especially when undertaken in response to their micro-level uncertainties.

4.6.2.2 Site visits/pre-demolition audits

Even if drawings and asbestos registers are available, interviewees indicated that demolishers conduct site visits and pre-demolition audits to gather the required information for building dismantling. Interviewee BD2 asserted that conducting several site visits during a dismantling project is important for two reasons. Firstly, if the contractor/developer/client permits a site visit before tendering, it is helpful as it allows the demolisher to offer a competitive bid for the dismantling project. Secondly, after getting the job, the demolisher needs to conduct a site visit to understand the 'as-is' condition of the building. Interviewee BD2 explained how he ascertained the 'as-is' condition of a building during a site visit:

> You need to conduct a site visit and measure everything in your mind; it requires experience. Now I always measure it. You need to transfer the building or the demolition, whether it's trees, bitumen or building; you have to convert that to tons of cubic metres. This is my methodology. Then you put it on paper. From the houses, you understand what a machine can process. You've done other work, and you have an understanding.

Interviewee BD5 revealed that undertaking a site visit and pre-demolition audit is imperative to recognise the presence of asbestos and other hazardous substances in a building. Furthermore, a site visit is a good opportunity for the demolisher to clarify whether the information in the asbestos register is contemporary and accurate;

> We need to inspect the asbestos register carefully by having an on-site visit. What's going on here? What chemicals have been used; we need that. We won't do the job without that. (Interviewee BD5)

Interviewees also highlighted that pre-demolition site visits and audits help demolishers to extract the information required to confront uncertainties related to health and safety. Interviewee BD1 emphasised that site visits before dismantling enabled them to assess the dangers and effectively plan their job. On the same note, Interviewee BD3 echoed that repetitive site visits and audits, even during the job, are recommended in their organisation.

4.6.2.3 Performance evaluation of sub-contractors

Interviewees identified the 'performance evaluation of sub-contractors' as an IPM for QA in RLSCs of DW. Interviewee SG3 asserted that the DW management industry continues to be labour-oriented despite incorporating many machines and much equipment. Therefore, recruiting a skilful workforce and enhancing their competency profiles are important. For instance, Interviewee BD1 stated that demolition companies incorporate many sub-contractors with different work trades whenever they offer a new project. Therefore, before recruiting sub-contractors for the job, a comprehensive performance evaluation is vital to ensure they possess the necessary skills and competencies:

> I would just get to interview the people and see their general experience, how they interview, how they look and what they say. Whether they have good experience in what they do, how they're going to treat their machines or our equipment: there are many things we look at to see whether we want to have that person. As I've said, their qualification and general dedication to the job are not used for employing somebody in demolition or [in] a traction machine; they've got to have some experience [to] work with us. (Interviewee BD1)

Interviewee BD4 mentioned that incorporating a skilful and experienced workforce guarantees that workers possess the knowledge and are aware of the required information to effectively and efficiently do the job. Interviewee BD7 revealed that, in most cases, demolishers incorporate sub-contractors who have lengthy experience working with them on many projects. In this way, the demolisher receives assurance about their work, therefore knowing they will not disturb the QA of the entire demolition job.

4.6.3 IPMs exclusive to waste processors

Interviewees identified three IPMs exclusively undertaken by waste processors in response to IPNs arising from epistemic uncertainties. The following subsections explain each of them in detail.

4.6.3.1 Creation of integrator roles

Interviewees revealed that waste-processing organisations are 'creating integrator roles' known as 'Accounts Managers' whose primary responsibility is to develop relationships with demolishers. Interviewee WP3 highlighted the importance of developing lengthy relationships with demolishers as they are the main input customers of a waste processing organisation. Accounts Managers set the price for each waste stream

accepted by the waste processing organisation. This ensures that the demolisher will not deliver mixed waste but will deliver separate waste streams that comply with the waste processor's acceptance criteria. In particular, Interviewee WP8 stated that:

> What Accounts Managers do when it's a customer who's maybe got a less than perfect reputation is they'll try and get to the sites and deal with it *in situ* before waste gets to us. They have talked with those contractors as a group trying to educate. So, they try and work with them via an educational approach. And then that encourages them to do the right thing instead of having to reject a load as the last resort as this costs everyone time and money.

Accordingly, on the one hand, as Accounts Managers follow an educational approach, demolishers would become aware of the importance of adopting QA practices, such as deconstruction and source separation. On the other hand, Accounts Managers ensure that the demolisher is delivering a clean mix of the waste stream to the MRF and communicate this to the waste processor. As this role of 'Accounts Manager' represents an organisational position in the boundary-spanning activities of waste processors, this IPM is named 'creating integrator roles' in this study.

4.6.3.2 Waste acceptance criteria/gate fees

Interviewees acknowledged that waste acceptance criteria and associated gate fees are wide-ranging and an effective IPM employed by waste processors to ensure they are not receiving mixed waste from demolishers. Interviewee WP6 explained that the waste acceptance criteria outline different waste streams that the waste processor should accept and their corresponding gate fees are based on regulations and organisational requirements. Therefore, waste acceptance criteria provide information and guide spotters and other workers at the weighbridge in refusing to accept any waste streams that do not comply with the waste acceptance criteria:

> Waste acceptance criteria are a really strict protocol around what we can accept. We can't accept soil, no asbestos and green waste, but we could accept general waste. We have a landfill for contaminated soil. So again, if a customer comes over the weighbridge to unload, we can't accept all of that. There are rules around how much we can dispose of without being tested. So, we stick to those protocols. It is 100 tons per site. (Interviewee WP6)

On the other hand, the waste acceptance criteria inform demolishers of the basis on which they should sort and deliver the waste to the MRF. Interviewee WP5 revealed that professional demolishers always consider transferring waste based on waste acceptance criteria to avoid paying more money as gate fees to waste processors.

> … demolishers segregate stuff out and then make sure the loads go because they would not want to pay us more. They want to ensure they pay the least possible for each trip. So, I think that through economic incentives, the demolition companies have got better at it. And conversely, it's been less of an issue for waste processors. (Interviewee WP5)

Interviewee SG2 asserted that it is ineffective to have waste acceptance criteria without diffusing this information to demolishers. Therefore, it is also important to develop contracts (see Subsection 4.6.1.4) and to assign Accounts Manager roles (see Subsection 4.6.3.1) to disseminate the waste acceptance criteria to demolishers.

4.6.3.3 Creation of special reports

Interviewees identified that obtaining feedback from end-users about the quality of reprocessed products is a significant IPM of waste processors. Interviewee WP6 stated that developing specifications and producing products in line with those specifications are important; however, on their own, they are not adequate to overcome product description complexities. Interviewee WP6 raised the point that it was necessary to collect feedback about reprocessed products from the market to recognise areas where improvements could be made in the production process:

> We're always taking feedback, but we have that standard [to which] we manufacture. Then we produce a homogenous product. But you know, we always talk to our customers, and if there are areas for improvement, we'll listen and take it on board. (Interviewee WP6)

Interviewee WP1 shared one of the experiences where his organisation changed the production process due to continuous negative feedback from customers over a reprocessed product:

> A while ago, our product was, … people were saying it's too dry. So, you have to supply a product at OMC (i.e., optimum moisture content). So that OMC is that point in the middle where you can pile on the sand and compact it. And it stays together where it's just moist enough to stick together, but not too dry and not too wet. So, we had some feedback that our product was a bit dry, which impacts [upon] compaction. And we made some adjustments.

On the same point, Interviewee WP9 added that if products do not comply with the specified quality criteria as per test results, the DIT provides feedback to waste processors to improve their internal processes. Generally, the DIT avoids selecting suppliers for future projects if they have supplied non-conforming products. Thus, waste processors always try to provide products of the best quality:

> There should be some feedback to the organisation for each contract. That goes into a pre-qualification area where that contractor would have been allowed to work in that area (e.g., placing asphalt). They would be pre-qualified for that. These data are handed back to the contract and procurement area under the pre-qualification, and they might have their prequalification removed if they do poor performance and so on. There is a quality management framework that contractors work under. (Interviewee WP9)

With these statements, it is evident that collecting feedback from end-users is an IPM used by waste processors to improve their production process. As this approach gathers information about the quality issues of reprocessed products, in alignment with the OIPT literature, this IPM was named 'creation of special reports'.

The next section provides an information processing map for QA in RLSCs of DW, based on the findings presented in Sections 4.4, 4.5 and 4.6.

4.7 Information Processing Map for QA in RLSCs of DW

Through semi-structured interviews, the current study established how process, people, policy and technology contribute to the QA in RLSCs of DW (see Table 4.2). In addition, 16 epistemic uncertainties that lead to IPNs (see Table 4.3) and 15 IPMs (see Table 4.4) for QA were also identified during this data collection phase. Herein, as interesting findings, the researcher found new knowledge from some interactions that participants discuss across the concepts when organizing the body of gathered qualitative data. Previous studies pointed out that concept mapping is an effective way of allowing qualitative researchers to interact with data and their current cognitive structure to generate new knowledge in a creative and meaningful way (Ligita et al. 2022; Wilson, Mandich & Magalhães 2016). Given this, an information processing map was developed in the current study to organize and present meaningful knowledge from the gathered qualitative data, as illustrated in Table 4.5. Herein, on the one hand, it was found that all the epistemic uncertainties that lead to IPNs evolve due to lapses or issues in the aspects of the QAS. On the other hand, all the IPMs that could undertake in response to the epistemic uncertainties also evolve from the aspects of QAS. In light of this, the information processing map shown in Table 4.5 provides insights that **integrated aspects of process, people, policy, and technology are accountable for creating an information-centric environment that successfully responds to the epistemic uncertainties which are also created by those aspects of QAS**.

Table 4.5. Information processing map for QA in RLSCs of DW

Phases in the RLSC		Epistemic uncertainties that lead to IPNs	Aspects of the QAS	Aspects of the QAS: Process: Collection of building documents and asbestos registers	Process: Site visits/pre-demolition audits	Process: Creation of slack resources	Process: Creation of special reports	People: IPMs: Creation of integrator roles	People: IPMs: Performance evaluation of sub-contractors	People: IPMs: Group meetings	People: IPMs: Hierarchical referral	People: IPMs: Incorporation of self-contained groups	Policy: Rules and programs	Policy: Planning and goal setting	Policy: Business partnering	Policy: Waste acceptance criteria/gate fees	Policy: Forming contracts	Technology: Investment in technologies
Building dismantling and on-site processing	Macro-level	Regulatory uncertainties of the demolisher	Policy															
		Contractual uncertainties from FSC-upstream actors	Policy										•	•	•			
		Incentivising uncertainties of the demolisher	Policy															
	Meso-level	Management of demolisher's sub-contractors	People						•	•			•	•	•		•	
	Micro-level	'As-is' condition of the building	Process															
		Management of contaminated/hazardous substances	Process															
		Health and safety concerns of the demolisher	Process	•	•	•				•	•	•	•	•	•			•
		Workflow uncertainties of the demolisher	Process															

Phases in the RLSC		Epistemic uncertainties that lead to IPNs	Aspects of the QAS	Aspects of the QAS																				
				Process					People							Policy						Technology	
									IPMs														
				Collection of building documents and asbestos registers	Site visits/pre-demolition audits	Creation of slack resources	Creation of special reports		Creation of integrator roles	Performance evaluation of sub-contractors	Group meetings	Hierarchical referral	Incorporation of self-contained groups		Rules and programs	Planning and goal setting	Business partnering	Waste acceptance criteria/gate fees	Forming contracts		Investment in technologies	
Off-site waste processing	Macro-level	Regulatory uncertainties of the waste processor	Policy																				
		Contractual uncertainties from FSC-downstream actors	Policy												•	•	•						
		Incentivising uncertainties of the waste processor	Policy																				
	Meso-level	Mixed waste received from demolishers	Process						•						•	•	•	•	•				
	Micro-level	Product description complexities	Process																				
		Human errors	People																				
		Health and safety concerns of the waste processor	Process			•	•				•	•	•		•	•	•					•	
		Workflow uncertainties of the waste processor	Process																				

As shown in Table 4.5, epistemic uncertainties that lead to IPNs evolve due to lapses or issues in QAS aspects. For instance, **all three macro-level uncertainties (i.e., regulatory, contractual and incentivising) could occur due to lapses or issues in the 'policy' aspect of the QAS.** Moreover, the meso-level uncertainties during building dismantling and on-site processing phase (i.e., management of demolisher's sub-contractors) and off-site waste processing phase (i.e., mixed waste received from demolishers) could arise due to lapses or issues in the 'people' and 'process' aspects, respectively. Lapses or issues in the 'process' aspect could cause all four micro-level uncertainties during the building dismantling and on-site processing phase (i.e., 'as-is' condition of the building, management of contaminated/hazardous substances, health and safety concerns and workflow uncertainties). However, except for human errors which could evolve due to lapses or issues in the 'people' aspect, the remaining three micro-level uncertainties during the off-site waste processing phase could occur from the issues or lapses in the 'process' aspect in the QAS. Notably, **no epistemic uncertainties were found due to lapses or issues in the 'technology' aspect in the QAS.**

Another interesting finding of the study was that all IPMs represent each aspect of the QAS. Accordingly, most IPMs for QA evolve from the 'people' and 'policy' aspects. As shown in Table 4.5, **'rules and programs', 'planning and goal setting' and 'business partnering', that is, the IPMs representing the 'policy' aspect, could be undertaken in response to all epistemic uncertainties during both phases.** Notably, these are the only IPMs that could address the macro-level uncertainties of both phases. **The epistemic uncertainties that evolve due to lapses or issues in the 'policy' aspect could only be addressed through IPMs representing the same aspect.** Further to Table 4.5, the IPMs representing the 'process' aspect could only be undertaken in response to the micro-level uncertainties, especially those that evolve due to lapses or issues of the same aspect. It is also apparent that epistemic uncertainties that develop due to lapses or issues in the 'people' aspect, such as 'management of demolisher's sub-contractors', could be addressed through IPMs originating from the 'people' and 'technology' aspects, other than those created from the 'process' aspect. Notably, even if the aspect of 'technology' does not create any epistemic uncertainties, it creates an IPM that could undertake in responding to the micro-level epistemic uncertainties that occur due to other aspects of the QAS. **Therefore, the aspect of 'technology' plays a**

significant role in QA in RLSCs of DW as it does not create any of the epistemic uncertainties but creates appropriate IPMs to respond to the other epistemic uncertainties which evolve due to the other aspects in QAS.

Findings from analysis of the semi-structured interviews further posit that **epistemic uncertainties for QA do not exist on their own; instead, they have interactions with each other.** Therefore, regulatory uncertainties propagate their influence via incentivising uncertainties through to contractual uncertainties. Accordingly, macro-level uncertainties were found to impact on meso- and micro-level uncertainties. The study also found that **the compounding effect of the demolisher's epistemic uncertainties increased the waste processors' epistemic uncertainties**. Therefore, a detailed investigation which models epistemic uncertainties while examining their interdependent impact on QA is important, with this described in the next chapters.

4.8 Concluding Remarks

This chapter presented the analysis of qualitative data collected from the semi-structured interviews. The interview data established how aspects of process, people, policy and technology contributed to QA in RLSCs of DW. The epistemic uncertainties which lead to IPNs and IPMs for QA were then identified. Accordingly, 16 epistemic uncertainties and 15 IPMs were identified. Building upon the directed content analysis results, an information processing map was developed for QA in RLSCs of DW. This information processing map provides insights into the relationships between aspects of QA, epistemic uncertainties and IPMs. Accordingly, it was found that both epistemic uncertainties and IPMs could evolve from each aspect of the QAS. The epistemic uncertainties and IPMs identified in this chapter were then used to develop the information processing model for QA in RLSCs of DW, as discussed in more detail in Chapter 5.

5 Development of Bayesian Belief Network (BBN): Information Processing Causal Mapping for Quality Assurance

5.1 Introduction

Chapter 4 identified the epistemic uncertainties which lead to IPNs and IPMs for QA in RLSCs of DW. Accordingly, 16 epistemic uncertainties that lead to IPNs and 15 IPMs were identified. This chapter explores the cause-and-effect relationships between (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and the performance measurement criterion (i.e., QA); and (iii) IPMs and epistemic uncertainties, as ascertained by interviewees in the structured interviews. Through consolidating all the findings, the BBN-based conceptual information processing model for QA in RLSCs of DW is developed and presented in this chapter.

5.2 Demographic Information of Interviewees: Structured Interviews

Twenty (20) structured interviews were conducted to identify the cause-and-effect relationships between (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and the performance measurement criterion (i.e., QA); and (iii) IPMs and epistemic uncertainties. Table 5.1 presents the profile of interviewees, including information about their designation, type of organisation and years of experience. The interviews were conducted with practitioners with a minimum of 10 years of experience in the DW management sector and who were from the building dismantling and on-site processing and off-site waste processing sectors across SA. Furthermore, all interviewees held decision-making positions in their respective organisations.

As shown in Table 5.1, interviewees' average length of experience was 16 years. Interestingly, five of the 20 had more than 20 years of experience. The composition of interviewees, as shown in Table 5.1, revealed that 40% of the interviewees were from

the building dismantling and on-site processing phase, while 60% were engaged in off-site waste processing. During the interviews, interviewees had the opportunity to clarify explanations of some of the terminologies, specifically derived from the OIPT-related literature. The next section identifies the cause-and-effect relationships between epistemic uncertainties that lead to IPNs for QA in RLSCs of DW.

Table 5.1. Profile of interviewees (structured interviews)

Code	Designation	CDW management sector	Experience (Years)
SE1	Strategic Business Development Manager	Off-site waste processing	11
SE2	Environmental Officer	Off-site waste processing	21
SE3	Logistics Manager	Off-site waste processing	16
SE4	Accounts Manager	Off-site waste processing	10
SE5	Sales and Marketing Manager	Off-site waste processing	12
SE6	Operations Manager	Off-site waste processing	24
SE7	Accounts Manager	Off-site waste processing	16
SE8	Group Environment Manager	Off-site waste processing	19
SE9	Human Resource and Occupational Health and Safety Manager	Off-site waste processing	12
SE10	State Operations Manager	Off-site waste processing	11
SE11	Compliance Manager	Off-site waste processing	15
SE12	Strategic Development and Business Improvement Manager	Off-site waste processing	13
SE13	Managing Director	Building dismantling and on-site processing	28
SE14	Sales and Marketing Manager	Building dismantling and on-site processing	18
SE15	Human Resource and Occupational Health and Safety Manager	Building dismantling and on-site processing	12
SE16	Managing Director	Building dismantling and on-site processing	24
SE17	Sales and Marketing Manager	Building dismantling and on-site processing	18
SE18	Project Manager	Building dismantling and on-site processing	16
SE19	Project Engineer	Building dismantling and on-site processing	10
SE20	Managing Director	Building dismantling and on-site processing	22

5.3 Cause-and-Effect Relationships between Epistemic Uncertainties that Lead to IPNs for QA in RLSCs of DW

This section describes the cause-and-effect relationships identified between epistemic uncertainties, which lead to IPNs, and each epistemic uncertainty and the performance measurement criterion (i.e., QA in RLSCs of DW). As explained in Chapter 4, the semi-structured interviews found 16 epistemic uncertainties, comprising six macro-level, two meso-level and eight micro-level uncertainties, as shown in Table 5.2. Some micro- and

macro-level uncertainties are common to the building dismantling and on-site processing phase and the off-site waste processing phase, while some are specific to one of these phases. The relevant notations for each uncertainty ($X_{1,2,3,4,\ldots\ldots 20}$) and the performance measurement criterion (Y) are provided in Table 5.2.

Table 5.2. Labelling epistemic uncertainties for the causal map

No.	Notation	Nodes in the causal map	Type of uncertainty	Phase in the RLSC
Chance nodes (Epistemic uncertainties that lead to IPNs for QA)				
1	X_1	Regulatory uncertainties of the demolisher	Macro-level	Building dismantling and on-site processing
2	X_2	Incentivising uncertainties of the demolisher		
3	X_3	Contractual uncertainties from FSC-upstream actors		
4	X_4	Management of demolisher's sub-contractors	Meso-level	
5	X_5	'As-is' condition of the building	Micro-level	
6	X_6	Management of contaminated/ hazardous substances		
7	X_7	Health and safety concerns of the demolisher		
8	X_8	Workflow uncertainties of the demolisher		
9	X_9	Regulatory uncertainties of the waste processor	Macro-level	Off-site waste processing
10	X_{10}	Incentivising uncertainties of the waste processor		
11	X_{11}	Contractual uncertainties from FSC-downstream actors		
12	X_{12}	Mixed waste received from the demolishers	Meso-level	
13	X_{13}	Product description complexities	Micro-level	
14	X_{14}	Human errors		
15	X_{15}	Health and safety concerns of the waste processor		
16	X_{16}	Workflow uncertainties of the waste processor		
Performance measurement criterion				
17	Y	QA in RLSCs of DW		

A matrix was developed for the structured interviews by incorporating these epistemic uncertainties and the performance measurement criterion (see Appendix 2[C]). Interviewees were asked to determine the strength of relationships between each pair of epistemic uncertainties and each epistemic uncertainty and the performance measurement criterion. After the interviews, 256 cause-and-effect relationships were obtained. These relationships were evaluated using the nine logical tests described in

Chapter 3, Subsection 3.5.2.2.1 (see Chapter 3, Figure 3.5). Table 5.3 summarises the accepted and rejected relationships after this evaluation process.

Table 5.3. Summary of accepted and rejected cause-and-effect relationships between epistemic uncertainties

Logical test/Data evaluation test	Number of relationships	Relationship accepted/ rejected
F1	153	Rejected
F2	13	Rejected
F3	14	Rejected
F4	17	Accepted
F5	26	Accepted
F6	1	Accepted
F7	15	Accepted
F8	10	Accepted
F9	7	Rejected
Total cause-and-effect relationships = 256		
Total accepted relationships = 69		
Total rejected relationships = 187		

As shown in Table 5.3, 69 cause-and-effect relationships were accepted, while the remaining 187 relationships were rejected. The accepted cause-and-effect relationships are outlined in Table 5.4, including their cause-and-effect variables, calculated average, skewness and |W-S|. As described in Chapter 3, Subsection 3.5.2.2.1, the notation ‘weak (W)’ indicated the number of experts who scored the relationship as either 0 or 1, while the notation ‘strong (S)’ indicated the number of experts scoring the relationship as 2 or 3. The difference between these two values, that is, ‘W’ and ‘S’, indicated the measure of the weight of the experts’ opinions.

Table 5.4. Details of accepted cause-and-effect relationships between epistemic uncertainties

Accepted relationships				Average	Skewness Value	|W-S|	Accepted Logical test
Rank	Notation	Cause	Effect				
1	X_{12}-Y	Mixed waste received from the demolishers	QA in RLSCs of DW	2.70	-0.9453	20	F4
2	X_6-X_7	Management of contaminated/hazardous substances	Health and safety concerns of the demolisher	2.65	-0.6812	20	F4
3	X_5-X_6	'As-is' condition of the building	Management of contaminated/hazardous substances	2.60	-0.4421	20	F4
4	X_{12}-X_{16}	Mixed waste received from the demolishers	Workflow uncertainties of the waste processor	2.60	-0.4421	20	F4
5	X_3-X_5	Contractual uncertainties from FSC-upstream actors	'As-is' condition of the building	2.60	-0.4421	20	F4
6	X_1-X_3	Regulatory uncertainties of the demolisher	Contractual uncertainties from FSC-upstream actors	2.60	-1.2455	18	F4
7	X_8-Y	Workflow uncertainties of the demolisher	QA in RLSCs of DW	2.55	-0.2177	20	F4
8	X_9-X_{11}	Regulatory uncertainties of the waste processor	Contractual uncertainties from FSC-downstream actors	2.55	-0.2177	20	F4
9	X_1-X_2	Regulatory uncertainties of the demolisher	Incentivising uncertainties of the demolisher	2.55	-0.2177	20	F4
10	X_{13}-Y	Product description complexities	QA in RLSCs of DW	2.55	-0.2177	20	F4
11	X_{16}-Y	Workflow uncertainties of the waste processor	QA in RLSCs of DW	2.55	-1.0032	18	F4
12	X_5-X_7	'As-is' condition of the building	Health and safety concerns of the demolisher	2.50	0.0000	20	F4
13	X_2-X_3	Incentivising uncertainties of the demolisher	Contractual uncertainties from FSC-upstream actors	2.50	0.0000	20	F4
14	X_6-X_8	Management of contaminated/hazardous substances	Workflow uncertainties of the demolisher	2.50	0.0000	20	F4
15	X_9-X_{10}	Regulatory uncertainties of the waste processor	Incentivising uncertainties of the waste processor	2.50	0.0000	20	F4
16	X_{14}-X_{16}	Human errors	Workflow uncertainties of the waste processor	2.50	-0.7845	18	F4
17	X_6-Y	Management of contaminated/hazardous substances	QA in RLSCs of DW	2.50	-0.7845	18	F4
18	X_{11}-X_{13}	Contractual uncertainties from FSC-downstream actors	Product description complexities	2.45	0.2177	20.00	F5
19	X_{14}-X_{15}	Human errors	Health and safety concerns of the waste processor	2.45	-1.0165	14.00	F5
20	X_6-X_{12}	Management of contaminated/hazardous substances	Mixed waste received from the demolishers	2.40	-0.7124	16.00	F5
21	X_{13}-X_{16}	Product description complexities	Workflow uncertainties of the waste processor	2.40	0.4421	20.00	F5
22	X_7-X_8	Health and safety concerns of the demolisher	Workflow uncertainties of the demolisher	2.35	-0.2124	18.00	F5

Rank	Accepted relationships			Average	Skewness Value	|W-S|	Accepted Logical test
	Notation	Cause	Effect				
23	X_{10}-X_{11}	Incentivising uncertainties of the waste processor	Contractual uncertainties from FSC-downstream actors	2.35	-0.5492	16.00	F5
24	X_5-X_8	'As-is' condition of the building	Workflow uncertainties of the demolisher	2.30	-0.3960	16.00	F5
25	X_8-X_{12}	Workflow uncertainties of the demolisher	Mixed waste received from the demolishers	2.30	-0.3960	16.00	F5
26	X_{15}-X_{16}	Health and safety concerns of the waste processor	Workflow uncertainties of the waste processor	2.30	-0.0376	18.00	F5
27	X_3-X_4	Contractual uncertainties from FSC-upstream actors	Difficulty in managing demolisher's sub-contractors	2.20	-0.1203	16.00	F5
28	X_5-X_{12}	As-is condition of the building	Mixed waste received from the demolishers	2.20	0.2941	18.00	F5
29	X_1-X_8	Regulatory uncertainties of the demolisher	Workflow uncertainties of the demolisher	2.15	-0.0043	16.00	F5
30	X_4-X_8	Management of demolisher's sub-contractors	Workflow uncertainties of the demolisher	2.10	-0.0800	14.00	F5
31	X_5-Y	As-is condition of the building	QA in RLSCs of DW of DW	2.10	0.5492	18.00	F5
32	X_8-X_{16}	Workflow uncertainties of the demolisher	Workflow uncertainties of the waste processor	2.10	0.0832	16.00	F5
33	X_{10}-X_{14}	Incentivising uncertainties of the waste processor	Human errors	2.10	0.0832	16.00	F5
34	X_{10}-X_{16}	Incentivising uncertainties of the waste processor	Workflow uncertainties of the waste processor	2.10	-0.1516	12.00	F5
35	X_9-X_{12}	Regulatory uncertainties of the waste processor	Mixed waste received from the demolishers	2.05	0.1121	16.00	F5
36	X_9-X_{15}	Regulatory uncertainties of the waste processor	Health and safety concerns of the waste processor	2.05	-0.8882	14.00	F5
37	X_3-X_6	Contractual uncertainties from FSC-upstream actors	Management of contaminated/hazardous substances	2.00	0.0000	16.00	F5
38	X_9-X_{16}	Regulatory uncertainties of the waste processor	Workflow uncertainties of the waste processor	2.00	0.0000	14.00	F5
39	X_{14}-X_{12}	Human errors	Mixed waste received from the demolishers	2.00	0.0000	12.00	F5
40	X_3-X_7	Contractual uncertainties from FSC-upstream actors	Health and safety concerns of the demolisher	1.95	-0.72	12.00	F5
41	X_{15}-Y	Health and safety concerns of the waste processor	QA in RLSCs of DW	2.00	0.0000	12.00	F5
42	X_{14}-Y	Human errors	QA in RLSCs of DW	2.00	0.0000	12.00	F5
43	X_1-X_6	Regulatory uncertainties of the demolisher	Management of contaminated/hazardous substances	2.00	0.0000	12.00	F5
44	X_6-X_{16}	Management of contaminated/hazardous substances	Workflow uncertainties of the waste processor	2.00	-0.2816	2.00	F6
45	X_7-Y	Health and safety concerns of the demolisher	QA in RLSCs of DW	1.85	0.1773	8.00	F7
46	X_4-X_{12}	Management of demolisher's sub-contractors	Mixed waste received from the demolishers	1.80	-0.1939	6.00	F7
47	X_{12}-X_{15}	Mixed waste received from the demolishers	Health and safety concerns of the waste processor	1.80	0.2916	6.00	F7
48	X_1-X_7	Regulatory uncertainties of the demolisher	Health and safety concerns of the demolisher	1.75	0.2525	6.00	F7
49	X_3-X_8	Contractual uncertainties from FSC-upstream actors	Workflow uncertainties of the demolisher	1.70	-0.0546	4.00	F8
50	X_{10}-X_{15}	Incentivising uncertainties of the waste processor	Health and safety concerns of the waste processor	1.70	-0.0546	4.00	F8

Rank	Accepted relationships			Average	Skewness Value	|W-S|	Accepted Logical test
	Notation	Cause	Effect				
51	X_3-Y	Contractual uncertainties from FSC-upstream actors	QA in RLSCs of DW	1.65	0.5492	2.00	F7
52	X_4-X_7	Management of demolisher’s sub-contractors	Health and safety concerns of the demolisher	1.65	-0.1505	-4.00	F8
53	X_8-X_4	Workflow uncertainties of the demolisher	Management of demolisher's sub-contractors	1.65	-0.6131	6.00	F8
54	X_2-X_8	Incentivising uncertainties of the demolisher	Workflow uncertainties of the demolisher	1.60	-0.4421	4.00	F7
55	X_2-X_{12}	Incentivising uncertainties of the demolisher	Mixed waste received from the demolishers	1.60	0.0327	2.00	F8
56	X_6-X_{15}	Management of contaminated/hazardous substances	Health and safety concerns of the waste processor	1.60	0.3933	2.00	F7
57	X_{11}-X_{16}	Contractual uncertainties from FSC-downstream actors	Workflow uncertainties of the waste processor	1.60	-0.4421	4.00	F7
58	X_2-X_6	Incentivising uncertainties of the demolisher	Management of contaminated/hazardous substances	1.55	0.5829	0.00	F7
59	X_2-X_7	Incentivising uncertainties of the demolisher	Health and safety concerns of the demolisher	1.55	-0.1981	2.00	F8
60	X_1-X_{12}	Regulatory uncertainties of the demolisher	Mixed waste received from the demolishers	1.55	-1.0032	4.00	F8
61	X_8-X_7	Workflow uncertainties of the demolisher	Health and safety concerns of the demolisher	1.55	-0.2177	2.00	F7
62	X_9-X_{13}	Regulatory uncertainties of the waste processor	Product description complexities	1.55	-0.1981	2.00	F8
63	X_9-X_{14}	Regulatory uncertainties of the waste processor	Human errors	1.55	-1.0032	4.00	F8
64	X_{10}-X_{12}	Incentivising uncertainties of the waste processor	Mixed waste received from the demolishers	1.55	-0.2177	2.00	F7
65	X_{10}-X_{13}	Incentivising uncertainties of the waste processor	Product description complexities	1.55	-0.1981	2.00	F7
66	X_{11}-Y	Contractual uncertainties from FSC-downstream actors	QA in RLSCs of DW	1.55	0.5829	0.00	F7
67	X_{12}-X_{14}	Mixed waste received from the demolishers	Human errors	1.55	-0.2177	2.00	F7
68	X_{16}-X_{14}	Workflow uncertainties of the waste processor	Human errors	1.55	-0.2177	2.00	F7
69	X_7-X_4	Health and safety concerns of the demolisher	Management of demolisher’s sub-contractors	1.50	0.0000	0.00	F8

As shown in Table 5.4, of all the accepted cause-and-effect relationships, X_{12}-Y (i.e., mixed waste received from demolishers–QA in RLSCs of DW) received the highest average of 2.70. Therefore, this is the strongest relationship. The relationships between micro-level uncertainties during the building dismantling and on-site waste processing phase, such as X_6-X_7 (i.e., management of contaminated/hazardous substances–health and safety concerns of demolisher) and X_5-X_6 (i.e., 'as-is' condition of the building–management of contaminated/hazardous substances) are the next strongest with the highest averages. Notably, among the top 10 cause-and-effect relationships (those with the highest averages, five relationships are between epistemic uncertainties of the demolisher. These relationships are X_6-X_7 (management of contaminated/hazardous substances–health and safety concerns of the demolisher); X_5-X_6 ('as-is' condition of the building–management of contaminated/hazardous substances); X_3-X_5 (contractual uncertainties from FSC-upstream actors–'as-is' condition of the building); X_1-X_3 (regulatory uncertainties of the demolisher–contractual uncertainties from FSC-upstream actors); and X_1-X_2 (regulatory uncertainties of the demolisher–incentivising uncertainties of the demolisher). Furthermore, the performance measurement criterion (i.e., Y. QA in RLSCs of DW) appears as the 'effect' in three of these top 10 relationships (those with the highest averages). In these relationships, the epistemic uncertainties which cause the performance criterion are mixed waste received from the demolishers (X_{12}), workflow uncertainties of the demolisher (X_8) and product description complexities (X_{13}). With these findings, it is evident that the relationships between epistemic uncertainties or relationships caused by epistemic uncertainties during the building dismantling and on-site processing phase appear at the top with the highest averages.

Three cause-and-effect relationships are found among the top 10 relationships (those with the highest averages) caused by the regulatory uncertainties of both demolisher (two relationships) and waste processor (one relationship). It was also found that regulatory uncertainties, irrespective of whether for the demolisher or the waste processor, occur in 13 of all 69 accepted cause-and-effect relationships. In these 13 relationships, regulatory uncertainties appeared as a cause but not an effect. Of all, seven are due to the waste processor's regulatory uncertainties, while the remaining six are due to the demolisher's regulatory uncertainties. All the epistemic uncertainties, except regulatory uncertainties, have appeared as both 'cause' and 'effect' variables in

the relationships. Therefore, this indicates that regulatory uncertainties are the root causes for the remaining macro-, meso- and micro-level uncertainties.

The relationship X_7-X_4 (i.e., health and safety concerns of the demolisher–management of demolisher's sub-contractors) has the lowest average of 1.50. Thus, it is the weakest relationship among all the accepted cause-and-effect relationships. As shown in Table 5.4, seven of the 10 relationships with the lowest averages are sourced from the epistemic uncertainties that arise during the off-site waste processing phase. Of all, five are specifically formed due to the waste processor's macro-level uncertainties, that is, the regulatory, incentivising and contractual uncertainties. Notably, of the 12 relationships with averages less than 1.55, eight are caused by macro-level uncertainties during both phases in RLSCs of DW. This emphasises that most relationships caused by macro-level uncertainties received low ranks with the lowest averages. Table 5.4 also reflects that most accepted cause-and-effect relationships have negative skewness, while a few relationships ranked at the bottom have positive skewness.

5.4 Causal Map before Inclusion of IPMs (Stage I)

All the accepted 69 cause-and-effect relationships were consolidated and modelled in a causal map, as shown in Figure 5.1.

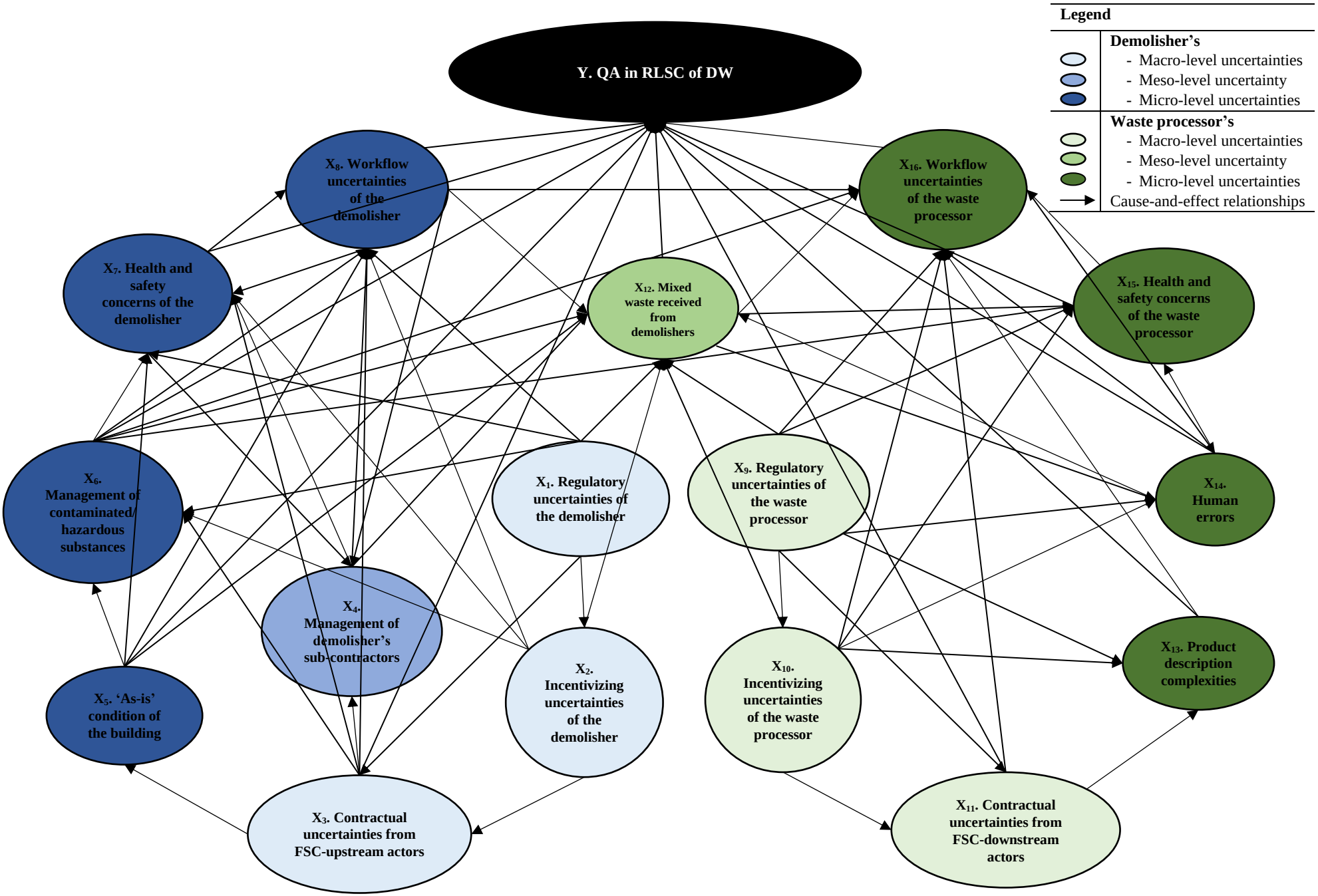


Figure 5.1. Causal map before inclusion of IPMs (Stage I)

As shown in Figure 5.1., the nodes represented by ovals indicate epistemic uncertainties (X) and Y. QA in RLSCs of DW which is the performance criterion of the study. The different colours represent the macro-level, meso-level and micro-level uncertainties separately during the building dismantling and on-site processing phase and the off-site waste processing phase, as indicated in the legend. The cause-and-effect relationships are indicated using arrows. As explained in Subsection 3.5.2.2.2, the node at the arrow's tail of each cause-and-effect relationship is the child node, and the node at the arrow's head is the parent node. Table 5.5 summarises the parent and child nodes of each epistemic uncertainty and the performance criterion, as shown in Figure 5.1.

Table 5.5. Parent and child nodes of each epistemic uncertainty and the performance criterion

Code	Epistemic uncertainty	Parent nodes	Child nodes
X_1	Regulatory uncertainties of the demolisher	-	X_2 - Incentivising uncertainties of the demolisher X_3 - Contractual uncertainties from FSC-upstream actors X_6 - Management of contaminated/ hazardous substances X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher X_{12} - Mixed waste received from demolishers
X_2	Incentivising uncertainties of the demolisher	X_1 - Regulatory uncertainties of the demolisher	X_3 - Contractual uncertainties from FSC-upstream actors X_6 - Management of contaminated/ hazardous substances X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher X_{12} - Mixed waste received from demolishers
X_3	Contractual uncertainties from FSC-upstream actors	X_1 - Regulatory uncertainties of the demolisher X_2 - Incentivising uncertainties of the demolisher	X_4 - Management of demolisher's sub-contractors X_5 – 'As-is' condition of the building X_6 - Management of contaminated/ hazardous substances X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher Y - QA in RLSCs of DW
X_4	Difficulty in managing demolisher's	X_3 - Contractual uncertainties from FSC-upstream actors	X_7 - Health and safety concerns of the demolisher

Code	Epistemic uncertainty	Parent nodes	Child nodes
	sub-contractors	X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher	X_8 - Workflow uncertainties of the demolisher X_{12} - Mixed waste received from demolishers
X_5	'As-is' condition of the building	X_3 - Contractual uncertainties from FSC-upstream actors	X_6 - Management of contaminated/ hazardous substances X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher X_{12} - Mixed waste received from demolishers Y - QA in RLSCs of DW
X_6	Management of contaminated/ hazardous substances	X_1 - Regulatory uncertainties of the demolisher X_2 - Incentivising uncertainties of the demolisher X_3 - Contractual uncertainties from FSC-upstream actors X_5 - 'As-is' condition of the building	X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher X_{12} - Mixed waste received from demolishers X_{15} - Health and safety concerns of the waste processor X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW
X_7	Health and safety concerns of the demolisher	X_1 - Regulatory uncertainties of the demolisher X_2 - Incentivising uncertainties of the demolisher X_3 - Contractual uncertainties from FSC-upstream actors X_4 - Management of demolisher's sub-contractors X_5 - 'As-is' condition of the building X_6 - Management of contaminated/ hazardous substances X_8 - Workflow uncertainties of the demolisher	X_4 - Management of demolisher's sub-contractors X_8 - Workflow uncertainties of the demolisher Y - QA in RLSCs of DW
X_8	Workflow uncertainties of the demolisher	X_1 - Regulatory uncertainties of the demolisher X_2 - Incentivising uncertainties of the demolisher X_3 - Contractual uncertainties from FSC-upstream actors X_4 - Management of demolisher's sub-contractors X_5 - 'As-is' condition of the building X_6 - Management of contaminated/ hazardous substances X_7 - Health and safety concerns of the demolisher	X_4 - Management of demolishers' sub-contractors X_7 - Health and safety concerns of the demolisher X_{12} - Mixed waste received from demolishers X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW

Code	Epistemic uncertainty	Parent nodes	Child nodes
X_9	Regulatory uncertainties of the waste processor	-	X_{10} - Incentivising uncertainties of the waste processor X_{11} - Contractual uncertainties from FSC-downstream actors X_{12} - Mixed waste received from demolishers X_{13} - Product description complexities X_{14} - Human errors X_{15} - Health and safety concerns of the waste processor X_{16} - Workflow uncertainties of the waste processor
X_{10}	Incentivising uncertainties of the waste processor	X_9 - Regulatory uncertainties of the waste processor	X_{11} - Contractual uncertainties from FSC-downstream actors X_{12} - Mixed waste received from demolishers X_{13} - Product description complexities X_{14} - Human errors X_{15} - Health and safety concerns of the waste processor X_{16} - Workflow uncertainties of the waste processor
X_{11}	Contractual uncertainties from FSC-downstream actors	X_9 - Regulatory uncertainties of the waste processor X_{10} - Incentivising uncertainties of the waste processor	X_{13} - Product description complexities X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW
X_{12}	Mixed waste received from the demolisher	X_1 - Regulatory uncertainties of the demolisher X_2 - Incentivising uncertainties of the demolisher X_4 - Management of demolisher's sub-contractors X_5 - 'As-is' condition of the building X_6 - Management of contaminated/ hazardous substances X_8 - Workflow uncertainties of the demolisher X_9 - Regulatory uncertainties of the waste processor X_{10} - Incentivising uncertainties of the waste processor X_{14} - Human errors	X_{14} - Human errors X_{15} - Health and safety concerns of the waste processor X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW
X_{13}	Product description complexities	X_9 - Regulatory uncertainties of the waste processor X_{10} - Incentivising uncertainties of the waste processor X_{11} - Contractual uncertainties from FSC-downstream actors	X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW
X_{14}	Human errors	X_9 - Regulatory uncertainties of the waste processor X_{10} - Incentivising uncertainties of the waste processor X_{12} - Mixed waste received from demolishers	X_{12} - Mixed waste received from demolishers X_{15} - Health and safety concerns of the waste processor X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW

Code	Epistemic uncertainty	Parent nodes	Child nodes
		X_{16} - Workflow uncertainties of the waste processor	
X_{15}	Health and safety concerns of the waste processor	X_6 - Management of contaminated/ hazardous substances X_9 - Regulatory uncertainties of the waste processor X_{10} - Incentivising uncertainties of the waste processor X_{12} - Mixed waste received from demolishers X_{14} - Human errors	X_{16} - Workflow uncertainties of the waste processor Y - QA in RLSCs of DW
X_{16}	Workflow uncertainties of the waste processor	X_6 - Management of contaminated/ hazardous substances X_8 - Workflow uncertainties of the demolisher X_9 - Regulatory uncertainties of the waste processor X_{10} - Incentivising uncertainties of the waste processor X_{11} - Contractual uncertainties from FSC-downstream actors X_{12} - Mixed waste received from demolishers X_{13} - Product description complexities X_{14} - Human errors X_{15} - Health and safety concerns of the waste processor	Y - QA in RLSCs of DW
Y	QA in RLSCs of DW	X_3 - Contractual uncertainties from FSC-upstream actors X_5 - 'As-is' condition of the building X_6 - Management of contaminated/ hazardous substances X_7 - Health and safety concerns of the demolisher X_8 - Workflow uncertainties of the demolisher X_{11} - Contractual uncertainties from FSC-downstream actors X_{12} - Mixed waste received from demolishers X_{13} - Product description complexities X_{14} - Human errors X_{15} - Health and safety concerns of the waste processor X_{16} - Workflow uncertainties of the waste processor	-

As shown in Table 5.5, the performance criterion: 'Y. QA in RLSCs of DW' has the highest number of parent nodes (i.e., 11 parent nodes) without any child nodes. The nodes of both 'mixed waste received from demolishers (X_{12})' and 'workflow uncertainties of the waste processor (X_{16})' have the next highest number of parent nodes, each with nine nodes. On the other hand, 'regulatory uncertainties of the waste

processor (X_9)' has the highest number of child nodes (i.e., seven child nodes), followed by four nodes, each with six child nodes. These four nodes are 'regulatory uncertainties of the demolisher (X_1)'; 'contractual uncertainties from FSC-upstream actors (X_3)'; 'management of contaminated/hazardous substances (X_6)'; and 'incentivising uncertainties of the waste processor (X_{10})'. Notably, the nodes of 'regulatory uncertainties of demolisher (X_1)' and 'regulatory uncertainties of waste processor (X_9)' do not have parent nodes. Therefore, as shown in Figure 5.1, they are the root nodes of the causal map.

Figure 5.1 illustrates only Stage I of the causal map. It comprises the cause-and-effect relationships between epistemic uncertainties that lead to IPNs and each epistemic uncertainty and the performance measurement criterion, excluding the IPMs. Therefore, this causal map in Figure 5.1 was extended by incorporating IPMs, with Section 5.5 discussing this incorporation process.

5.5 Cause-and-Effect Relationships between IPMs and Epistemic Uncertainties that Lead to IPNs

As explained in Chapter 4, findings from the analysis of the semi-structured interviews identified 15 IPMs that internal stakeholders in RLSCs could undertake in response to their macro-, meso- and micro-level uncertainties. To incorporate these IPMs, an information processing map was developed and presented at the end of Chapter 4 (see Chapter 4, Table 4.5); however, this map did not indicate IPMs that could be undertaken in response to each epistemic uncertainty. Consequently, this section identifies the cause-and-effect relationships between IPMs (as causes) and epistemic uncertainties that lead to IPNs (as effects), intending to recognise the most appropriate IPMs that could be undertaken in response to each epistemic uncertainty. Table 5.6 summarises these IPMs and outlines the relevant notations used to develop the next stage (Stage II) of the causal map.

A different matrix was developed, comprising IPMs on the Y-axis and epistemic uncertainties that lead to IPNs on the X-axis (see Appendix 2[c]). Interviewees were asked to evaluate the strength of the relationships between each pair of an IPM and an epistemic uncertainty. After the interviews, 240 cause-and-effect relationships were obtained. A summary of the results obtained through evaluating these 240 relationships using nine logical tests (see Chapter 3, Figure 3.5) is presented in Table 5.7.

Table 5.6. Labelling IPMs for the causal map

No.	Notation	Decision nodes in the causal map (IPMs)
1	IPM_1	Rules and programs
2	IPM_2	Planning and goal setting
3	IPM_3	Business partnering
4	IPM_4	Collection of building documents and asbestos registers
5	IPM_5	Site visits/pre-demolition audits
6	IPM_6	Creation of integrator roles
7	IPM_7	Performance evaluation of sub-contractors
8	IPM_8	Waste acceptance criteria/gate fees
9	IPM_9	Forming contracts
10	IPM_{10}	Creation of special reports
11	IPM_{11}	Investment in technologies
12	IPM_{12}	Group meetings
13	IPM_{13}	Hierarchical referral
14	IPM_{14}	Incorporation of self-contained groups
15	IPM_{15}	Creation of slack resources

Table 5.7. Summary of accepted and rejected cause-and-effect relationships between IPMs and epistemic uncertainties

Logical test/Data evaluation test	Number of relationships	Relationship accepted/rejected
F1	154	Rejected
F2	5	Rejected
F3	3	Rejected
F4	22	Accepted
F5	26	Accepted
F6	0	Accepted
F7	10	Accepted
F8	13	Accepted
F9	7	Rejected
Total cause-and-effect relationships = 240		
Total accepted relationships = 71		
Total rejected relationships = 169		

As shown in Table 5.7, 71 cause-and-effect relationships were accepted, while the remaining (i.e., 169) relationships were rejected. Of the 240, a significant number of relationships (i.e., 154) were rejected from the first test as their averages were less than 1.01. Most of the relationships were accepted from tests F4 and F5. All these accepted cause-and-effect relationships (71) are presented in Table 5.8, including details of their calculated average, skewness and |W-S| (see Chapter 3, Subsection 3.5.1.2).

Table 5.8. Accepted cause-and-effect relationships between IPMs and epistemic uncertainties

Accepted relationships				Average	Skewness Value	|W-S|	Accepted Logical Test
Rank	**Notation**	**Causes (IPMs)**	**Effects (Epistemic uncertainties that lead to IPNs)**				
1	IPM_8-X_{12}	Waste acceptance criteria/gate fees	Mixed waste received from the demolishers	2.95	-4.47	20.00	F4
2	IPM_4-X_5	Collection of building documents and asbestos registers	'As-is' condition of the building	2.95	-4.47	20.00	F4
3	IPM_{14}-X_6	Incorporation of self-contained groups	Management of contaminated/hazardous substances	2.90	-2.89	20.00	F4
4	IPM_5-X_5	Site visits/pre-demolition audits	'As-is' condition of the building	2.90	-2.89	20.00	F4
5	IPM_9-X_4	Forming contracts	Management of demolisher's sub-contractors	2.85	-2.12	20.00	F4
6	IPM_4-X_7	Collection of building documents and asbestos registers	Health and safety concerns of the demolisher	2.85	-2.12	20.00	F4
7	IPM_{10}-X_{13}	Creation of special reports	Product description complexities	2.75	-2.24	18.00	F4
8	IPM_4-X_6	Collection of building documents and asbestos registers	Management of contaminated/hazardous substances	2.70	-0.95	20.00	F4
9	IPM_1-X_1	Rules and programs	Regulatory uncertainties of the demolisher	2.65	-1.52	18.00	F4
10	IPM_{14}-X_7	Incorporation of self-contained groups	Health and safety concerns of the demolisher	2.60	-0.44	20.00	F4
11	IPM_{11}-X_{15}	Investment in technologies	Health and safety concerns of the waste processor	2.60	-0.44	20.00	F4
12	IPM_{14}-X_{14}	Incorporation of self-contained groups	Human errors	2.60	-0.44	20.00	F4
13	IPM_1-X_9	Rules and programs	Regulatory uncertainties of the waste processor	2.60	-0.44	20.00	F4
14	IPM_{11}-X_{14}	Investment in technologies	Human errors	2.55	-1.00	18.00	F4
15	IPM_5-X_6	Site visits/pre-demolition audits	Management of contaminated/hazardous substances	2.55	-0.22	20.00	F4
16	IPM_2-X_{14}	Planning and goal setting	Human errors	2.55	-1.00	18.00	F4
17	IPM_5-X_7	Site visits/pre-demolition audits	Health and safety concerns of the demolisher	2.55	-1.00	18.00	F4
18	IPM_7-X_4	Performance evaluation of sub-contractors	Management of demolisher's sub-contractors	2.50	-0.78	18.00	F4
19	IPM_1-X_7	Rules and programs	Health and safety concerns of the demolisher	2.50	0.00	20.00	F4
20	IPM_2-X_7	Planning and goal setting	Health and safety concerns of the demolisher	2.50	0.00	20.00	F4
21	IPM_2-X_8	Planning and goal setting	Workflow uncertainties of the demolisher	2.50	0.00	20.00	F4
22	IPM_1-X_{10}	Rules and programs	Incentivising uncertainties of the waste processor	2.45	-1.02	14.00	F5
23	IPM_3-X_{12}	Business partnering	Mixed waste received from the demolishers	2.45	0.22	20.00	F5

24	IPM_{14}-X_{15}	Incorporation of self-contained groups	Health and safety concerns of the waste processor	2.45	0.22	20.00	F5
25	IPM_{1}-X_{6}	Rules and programs	Management of contaminated/hazardous substances	2.40	-0.71	16.00	F5
26	IPM_{1}-X_{2}	Rules and programs	Incentivising uncertainties of the demolisher	2.40	0.44	20.00	F5
27	IPM_{12}-X_{16}	Group meetings	Workflow uncertainties of the waste processor	2.40	-0.39	18.00	F5
28	IPM_{14}-X_{8}	Incorporation of self-contained groups	Workflow uncertainties of the demolisher	2.40	0.44	20.00	F5
29	IPM_{1}-X_{15}	Rules and programs	Health and safety concerns of the waste processor	2.35	-1.55	18.00	F5
30	IPM_{2}-X_{6}	Planning and goal setting	Management of contaminated/hazardous substances	2.30	-0.04	18.00	F5
31	IPM_{1}-X_{14}	Rules and programs	Human errors	2.30	-0.40	16.00	F5
32	IPM_{13}-X_{15}	Hierarchical referral	Health and safety concerns of the waste processor	2.30	-1.45	18.00	F5
33	IPM_{6}-X_{15}	Creation of integrator roles	Health and safety concerns of the waste processor	2.25	0.13	18.00	F5
34	IPM_{2}-X_{16}	Planning and goal setting	Workflow uncertainties of the waste processor	2.15	0.44	18.00	F5
35	IPM_{3}-X_{10}	Business partnering	Incentivising uncertainties of the waste processor	2.15	0.00	16.00	F5
36	IPM_{2}-X_{15}	Planning and goal setting	Health and safety concerns of the waste processor	2.15	-0.18	14.00	F5
37	IPM_{11}-X_{16}	Investment in technologies	Workflow uncertainties of the waste processor	2.15	-0.18	14.00	F5
38	IPM_{13}-X_{16}	Hierarchical referral	Workflow uncertainties of the waste processor	2.15	-0.95	14.00	F5
39	IPM_{1}-X_{16}	Rules and programs	Workflow uncertainties of the waste processor	2.10	-0.90	14.00	F5
40	IPM_{2}-X_{3}	Planning and goal setting	Contractual uncertainties from FSC-upstream actors	2.10	-0.08	14.00	F5
41	IPM_{2}-X_{13}	Planning and goal setting	Product description complexities	2.10	0.08	16.00	F5
42	IPM_{3}-X_{2}	Business partnering	Incentivising uncertainties of the demolisher	2.10	0.08	16.00	F5
43	IPM_{2}-X_{12}	Planning and goal setting	Mixed waste received from the demolishers	2.05	0.11	16.00	F5
44	IPM_{4}-X_{8}	Collection of building documents and asbestos registers	Workflow uncertainties of the demolisher	2.05	-0.01	14.00	F5
45	IPM_{13}-X_{14}	Hierarchical referral	Human errors	2.05	-1.15	16.00	F5
46	IPM_{2}-X_{11}	Planning and goal setting	Contractual uncertainties from FSC-downstream actors	2.00	0.00	12.00	F5
47	IPM_{14}-X_{16}	Incorporation of self-contained groups	Workflow uncertainties of the waste processor	2.00	0.00	14.00	F5
48	IPM_{11}-X_{6}	Investment in technologies	Management of contaminated/hazardous substances	1.95	0.06	10.00	F7
49	IPM_{6}-X_{12}	Creation of integrator roles	Mixed waste received from the demolishers	1.90	0.15	8.00	F7

50	IPM_1-X_{13}	Rules and programs	Product description complexities	1.90	-0.80	12.00	F8
51	IPM_{13}-X_8	Hierarchical referral	Workflow uncertainties of the demolisher	1.90	-0.08	12.00	F7
52	IPM_{12}-X_8	Group meetings	Workflow uncertainties of the demolisher	1.90	-0.80	12.00	F8
53	IPM_{15}-X_7	Creation of slack resources	Health and safety concerns of the demolisher	1.90	-0.08	12.00	F7
54	IPM_{12}-X_7	Group meetings	Health and safety concerns of the demolisher	1.90	-0.08	12.00	F7
55	IPM_{13}-X_7	Hierarchical referral	Health and safety concerns of the demolisher	1.80	-0.40	8.00	F8
56	IPM_{15}-X_{15}	Creation of slack resources	Health and safety concerns of the waste processor	1.75	-0.13	8.00	F7
57	IPM_5-X_8	Site visits/pre-demolition audits	Workflow uncertainties of the demolisher	1.75	-2.24	12.00	F8
58	IPM_9-X_{12}	Forming contracts	Mixed waste received from the demolishers	1.70	0.40	4.00	F7
59	IPM_{12}-X_4	Group meetings	Management of demolisher's sub-contractors	1.70	-0.95	8.00	F7
60	IPM_{13}-X_5	Hierarchical referral	'As-is' condition of the building	1.70	-0.84	8.00	F8
61	IPM_{12}-X_{13}	Group meetings	Product description complexities	1.70	-0.95	8.00	F7
62	IPM_1-X_8	Rules and programs	Workflow uncertainties of the demolisher	1.70	0.04	6.00	F7
63	IPM_1-X_{12}	Rules and programs	Mixed waste received from the demolishers	1.65	-0.54	6.00	F8
64	IPM_{11}-X_{12}	Investment in technologies	Mixed waste received from the demolishers	1.65	-0.61	6.00	F8
65	IPM_{10}-X_{14}	Creation of special reports	Human errors	1.60	-0.40	4.00	F4
66	IPM_2-X_5	Planning and goal setting	'As-is' condition of the building	1.60	-0.79	6.00	F8
67	IPM_{15}-X_{16}	Creation of slack resources	Workflow uncertainties of the waste processor	1.60	-0.99	8.00	F8
68	IPM_{11}-X_8	Investment in technologies	Workflow uncertainties of the demolisher	1.60	-0.79	6.00	F8
69	IPM_{13}-X_6	Hierarchical referral	Management of contaminated/hazardous substances	1.55	-1.28	6.00	F8
70	IPM_{11}-X_7	Investment in technologies	Health and safety concerns of the demolisher	1.55	-1.00	4.00	F8
71	IPM_{15}-X_8	Creation of slack resources	Workflow uncertainties of the demolisher	1.50	-0.78	2.00	F8

Table 5.8 ranks the cause-and-effect relationships between IPMs and epistemic uncertainties that lead to IPNs based on the average value. Among all the accepted relationships, IPM_8-X_{12} (waste acceptance criteria/gate fees–mixed waste received from demolishers) and IPM_4-X_5 (collection of building documents and asbestos registers–'as-is' condition of the building) have the highest averages of 2.95 each. Both relationships of IPM_{14}-X_6 (incorporation of self-contained groups–management of contaminated/ hazardous substances) and IPM_5-X_5 (site visits/pre-demolition audits–'as-is' condition of the building) received an average of 2.90, the second-highest average amid all the accepted cause-and-effect relationships. Notably, among the top 10 cause-and-effect relationships (those with the highest averages), eight relationships were between IPMs and epistemic uncertainties of the demolisher. Furthermore, six of these eight relationships were between IPMs and micro-level uncertainties of the demolisher. Only IPM_8-X_{12} (waste acceptance criteria/gate fees–mixed waste received from the demolishers) and IPM_{10}-X_{13} (creation of special reports–product description complexities) were within the top 10 relationships and were epistemic uncertainties of the waste processor. Therefore, it is evident that the relationships between IPMs and epistemic uncertainties of the demolisher have received higher averages than those of the waste processor; thus, they have appeared in the top ranks.

The relationship IPM_{15}-X_8 (creation of slack resources–workflow uncertainties of the demolisher) has the lowest average of 1.50. Therefore, this was the weakest relationship among all the accepted relationships. Only four relationships were accepted, including the IPM of 'creation of slack resources (IPM_{15})'. Notably, all four of these relationships appeared in the bottom ranks with low averages. Among all the accepted relationships, IPM_{11}-X_7 (investment in technologies–health and safety concerns of the demolisher) and IPM_{13}-X_6 (hierarchical referral–management of contaminated/hazardous substances) are the relationships that received the second-lowest averages.

5.6 Causal Map after Inclusion of IPMs (Stage II)

The causal map (Stage I) in Figure 5.1 was expanded by incorporating all the accepted cause-and-effect relationships between IPMs and epistemic uncertainties, as outlined in Table 5.8. This extended version of the causal map after including IPMs is depicted in Figure 5.2.

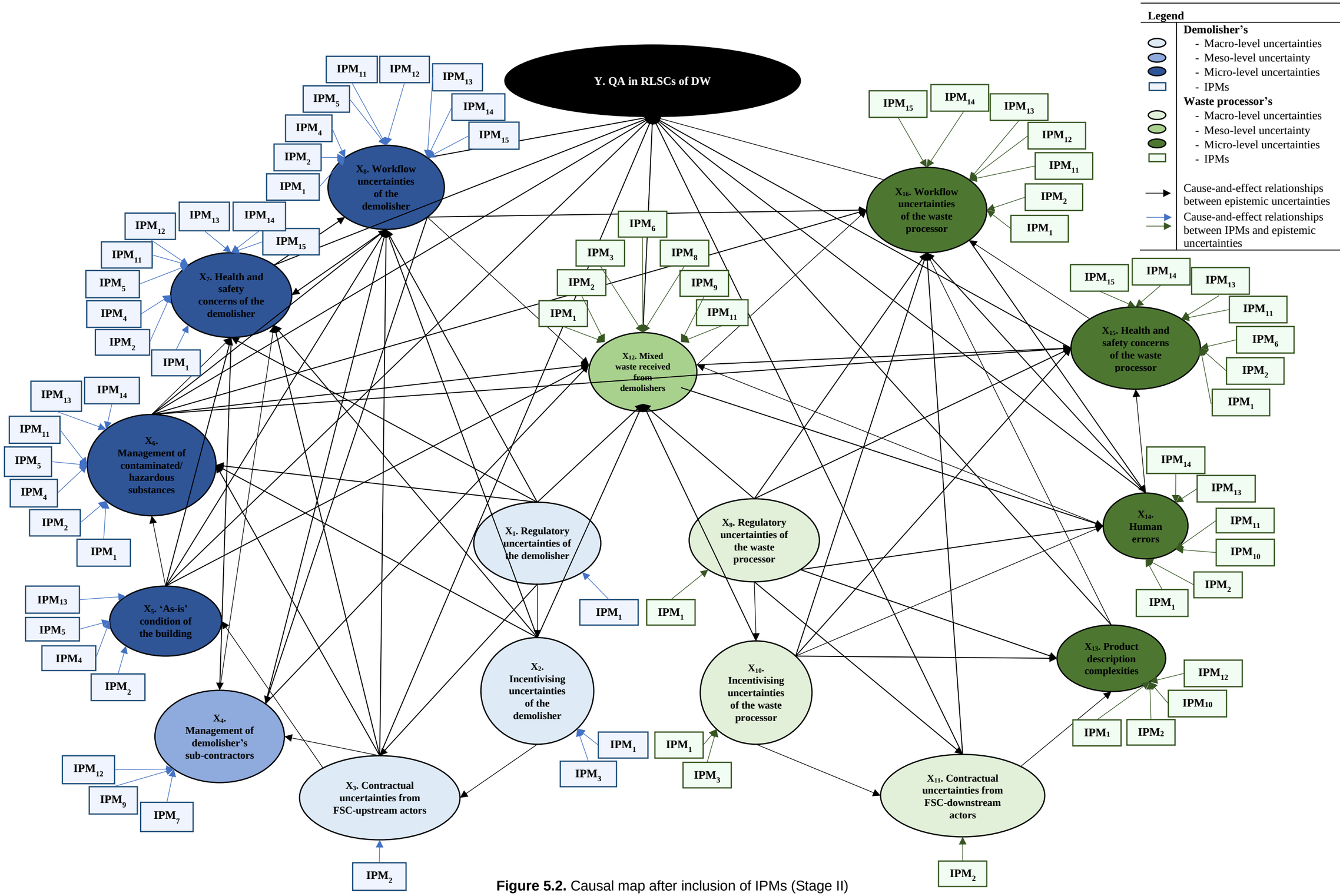


Figure 5.2. Causal map after inclusion of IPMs (Stage II)

In Figure 5.2, the blue and green rectangles denote the IPMs for epistemic uncertainties of the demolisher and waste processor, respectively. Furthermore, the impact of IPMs on epistemic uncertainties of the demolisher and waste processor is indicated using blue and green arrows, respectively. Most IPMs are available for 'health and safety concerns (X_7)' and 'workflow uncertainties (X_8)' of the demolisher. Notably, Figure 5.2 shows that the demolisher and waste processor could undertake a few IPMs in response to macro-level uncertainties that appear at the bottom (as root causes) of the causal map. The number of IPMs increases with the epistemic uncertainties propagating from the bottom to the top of the map. For instance, from the perspective of the demolisher, even if only 'rules and programs (IPM_1)' could be undertaken in response to regulatory uncertainties, nine IPMs are present to address workflow uncertainties. These nine are 'rules and programs (IPM_1)'; 'planning and goal setting (IPM_2)'; 'collection of building documents and asbestos registers (IPM_4)'; 'site visits/pre-demolition audits (IPM_5)'; 'investment in technologies (IPM_{11})'; 'group meetings (IPM_{12})'; 'hierarchical referral (IPM_{13})'; 'incorporation of self-contained groups (IPM_{14})'; and 'creation of slack resources (IPM_{15})'. A similar arrangement could also be found from the waste processor's perspective but varying the number of IPMs for each epistemic uncertainty. This finding emphasises that when epistemic uncertainties propagate and are compounded from the bottom upward, the number of IPMs that could be undertaken in response to these uncertainties also increases. Table 5.9 outlines IPMs that respond to each epistemic uncertainty of the demolisher and waste processor.

Table 5.9. IPMs for epistemic uncertainties that lead to IPNs

Phases in the RLSC	Type of epistemic uncertainty	Epistemic uncertainties that lead to IPNs	IPMs
Building dismantling and on-site processing	Macro-level	X_1. Regulatory uncertainties of the demolisher	IPM_1. Rules and programs
		X_2. Incentivising uncertainties of the demolisher	IPM_1. Rules and programs IPM_3. Business partnering
		X_3. Contractual uncertainties from FSC-upstream actors	IPM_2. Planning and goal setting
	Meso-level	X_4. Management of demolisher's sub-contractors	IPM_7. Performance evaluation of sub-contractors IPM_9. Forming contracts IPM_{12}. Group meetings
	Micro-level	X_5. 'As-is' condition of the building	IPM_2. Planning and goal setting IPM_4. Collection of building documents and asbestos registers IPM_5. Site visits/pre-demolition audits

Phases in the RLSC	Type of epistemic uncertainty	Epistemic uncertainties that lead to IPNs	IPMs
			IPM_{13}. Hierarchical referral
		X_6. Management of contaminated/hazardous substances	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_4. Collection of building documents and asbestos registers IPM_5. Site visits/pre-demolition audits IPM_{11}. Investment in technologies IPM_{13}. Hierarchical referral IPM_{14}. Incorporation of self-contained groups
		X_7. Health and safety concerns of the demolisher	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_4. Collection of building documents and asbestos registers IPM_5. Site visits/pre-demolition audits IPM_{11}. Investment in technologies IPM_{12}. Group meetings IPM_{13}. Hierarchical referral IPM_{14}. Incorporation of self-contained groups IPM_{15}. Creation of slack resources
		X_8. Workflow uncertainties of the demolisher	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_4. Collection of building documents and asbestos registers IPM_5. Site visits/pre-demolition audits IPM_{11}. Investment in technologies IPM_{12}. Group meetings IPM_{13}. Hierarchical referral IPM_{14}. Incorporation of self-contained groups IPM_{15}. Creation of slack resources
Off-site waste processing	Macro-level	X_9. Regulatory uncertainties of the waste processor	IPM_1. Rules and programs
		X_{10}. Incentivising uncertainties of the waste processor	IPM_1. Rules and programs IPM_3. Business partnering
		X_{11}. Contractual uncertainties from FSC-downstream actors	IPM_2. Planning and goal setting
	Meso-level	X_{12}. Mixed waste received from the demolishers	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_3. Business partnering IPM_6. Creation of integrator roles IPM_8. Waste acceptance criteria/gate fees IPM_9. Forming contracts IPM_{11}. Investment in technologies
	Micro-level	X_{13}. Product description complexities	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_{10}. Creation of special reports IPM_{12}. Group meetings
		X_{14}. Human errors	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_{10}. Creation of special reports IPM_{11}. Investment in technologies IPM_{13}. Hierarchical referral

Phases in the RLSC	Type of epistemic uncertainty	Epistemic uncertainties that lead to IPNs	IPMs
			IPM_{14}. Incorporation of self-contained groups
		X_{15}. Health and safety concerns of the waste processor	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_6. Creation of integrator roles IPM_{11}. Investment in technologies IPM_{13}. Hierarchical referral IPM_{14}. Incorporation of self-contained groups IPM_{15}. Creation of slack resources
		X_{16}. Workflow uncertainties of the waste processor	IPM_1. Rules and programs IPM_2. Planning and goal setting IPM_{11}. Investment in technologies IPM_{12}. Group meetings IPM_{13}. Hierarchical referral IPM_{14}. Incorporation of self-contained groups IPM_{15}. Creation of slack resources

As identified in Table 5.9, a notable feature of the causal map is that most IPMs repeatedly appear in response to many epistemic uncertainties. For example, 'rules and programs (IPM_1)' is an IPM for many epistemic uncertainties of the demolisher and waste processor. Furthermore, IPMs such as 'rules and programs (IPM_1)'; 'planning and goal setting (IPM_2)'; 'business partnering (IPM_3)'; 'forming contracts (IPM_9)'; 'investment in technologies (IPM_{11})'; 'group meetings (IPM_{12})'; 'hierarchical referral (IPM_{13})'; 'incorporation of self-contained groups (IPM_{14})'; and 'creation of slack resources (IPM_{15})' could be undertaken in response to epistemic uncertainties of both the demolisher and waste processor. On the other hand, some IPMs could be undertaken in response to a particular epistemic uncertainty of either the demolisher or waste processor. For instance, 'waste acceptance criteria/gate fees (IPM_8)' is an IPM that could be undertaken only in response to 'mixed waste received from demolishers (X_{12})'. Notably, these observations validate the findings consolidated in the information processing map developed in Chapter 4 (see Chapter 4, Table 4.5).

The arrangement of the causal map, as shown in Figure 5.2, has many decision and chance nodes, presenting a practical difficulty in analysing the epistemic uncertainties in the next stage. As described in Chapter 3, Subsection 3.5.2.3.2, a maximum limit of four to five nodes (either chance or decision nodes) for each variable is recommended to manage the number of probabilities that need to be obtained during the probability elicitation phase. However, more than five chance and decision nodes were attached to many epistemic uncertainties in the current causal map shown in Figure 5.2. For

instance, 16 nodes were identified as linked to the 'workflow uncertainties of the demolisher (X_8)'. This would require 2^{16} or 65,536 probabilities. Therefore, the causal map in Figure 5.2 was transformed into a BBN-based conceptual model by reducing its redundant relationships, following the principles of the causal mapping approach as discussed in Chapter 3, Subsection 3.5.2.2.2.

5.7 Transformation Process of Causal Map to a BBN-based Conceptual Model Using Principles of Causal Mapping Approach

After developing the causal map, a systematic procedure was established to construct a BBN-based conceptual model using the principles of the causal mapping approach (see Chapter 3, Subsection 3.5.2.2.2). These principles help to overcome the limitation of complexity in the causal map while making the next stage of probability elicitation easier. Given this point, the following subsections explain the transformation process through which the causal map is analysed in terms of: (i) eliminating circular relationships; (ii) distinguishing between direct and indirect relationships; and (iii) deductive reasoning underlying cause-and-effect relationships.

5.7.1 Eliminating circular relationships

The causal map (see Figure 5.2) comprises five circular relationships that do not comply with the acyclic graphical structure needed for a Bayesian network (see Chapter 3, Subsection 3.5.2.2.2[a]). Therefore, the circular loops between X_7-X_8, X_4-X_8, X_4-X_7, X_{14}-X_{12} and X_{14}-X_{16} were considered for elimination. As explained in Subsection 3.5.2.2.2(a), the links to be eliminated in the circular relationships were decided based on deductive versus abductive reasoning. The relationships with lower average values could be considered relationships with abductive reasoning. Figure 5.3 illustrates the five circular loops explaining their relationships in terms of deductive and abductive reasoning. Figure 5.3 also provides the average values of both types of relationships, as identified in Table 5.4.

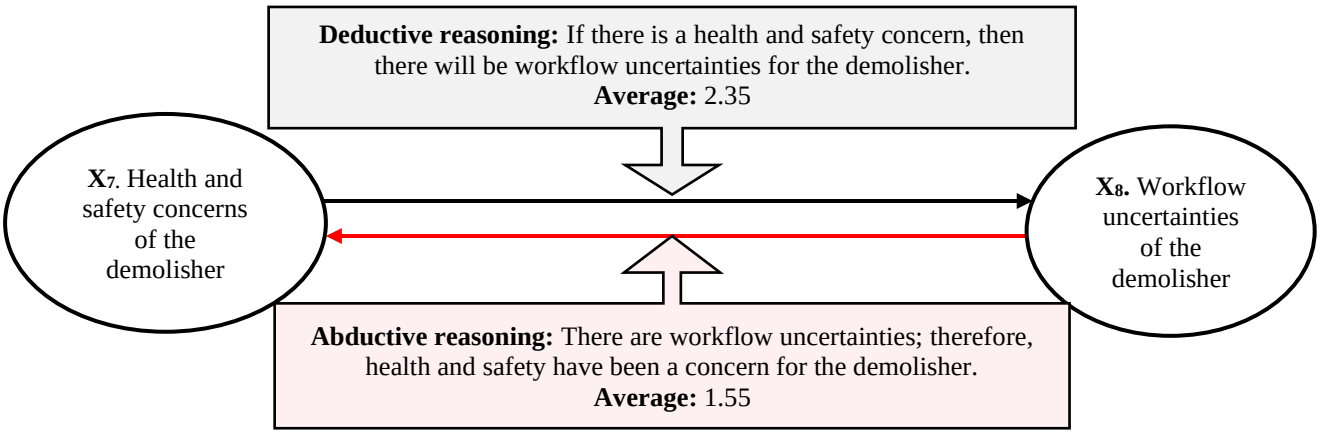


Figure 5.3A. Circular relationship between X_7 and X_8

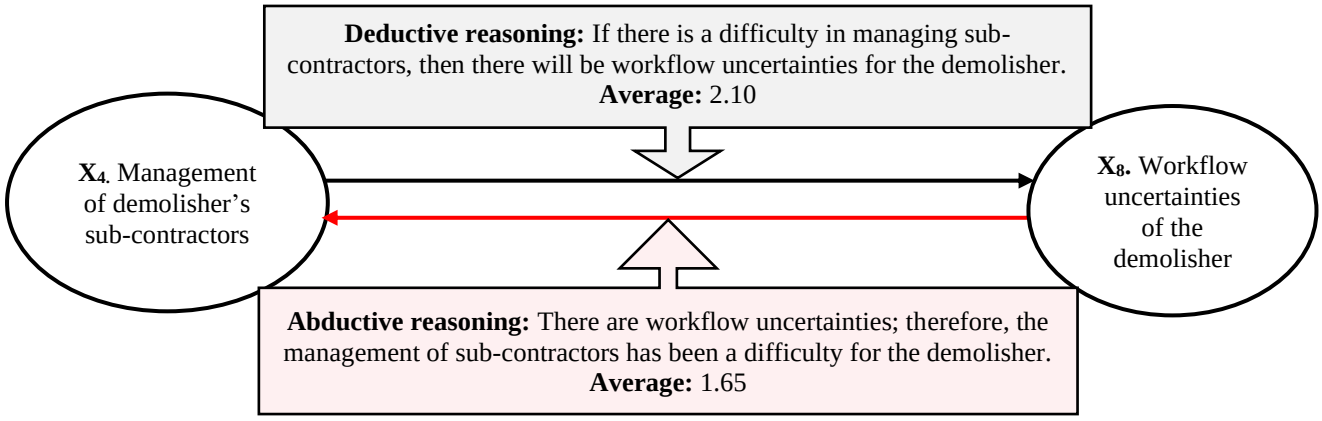


Figure 5.3B. Circular relationship between X_4 and X_8

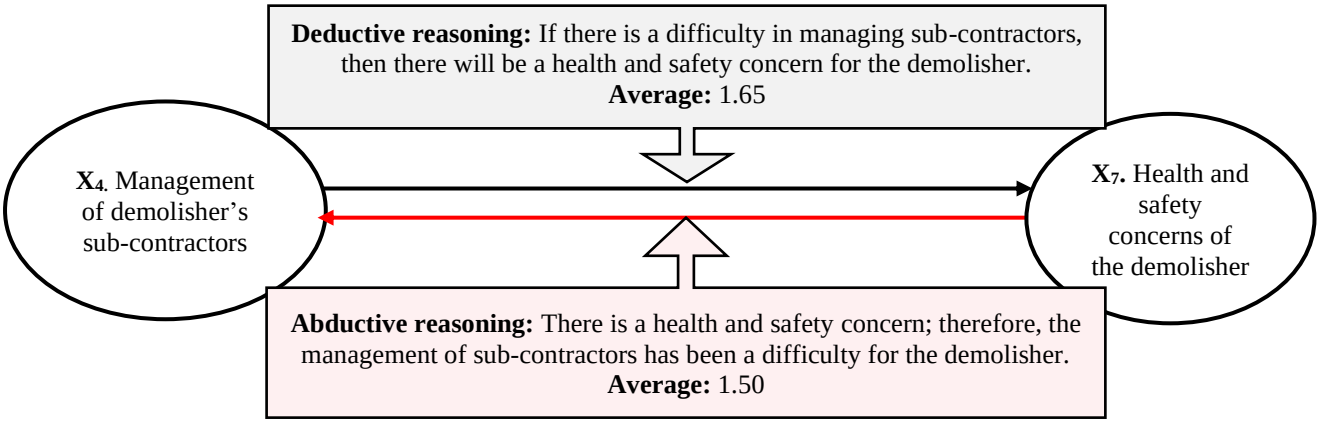


Figure 5.3C. Circular relationship between X_4 and X_7

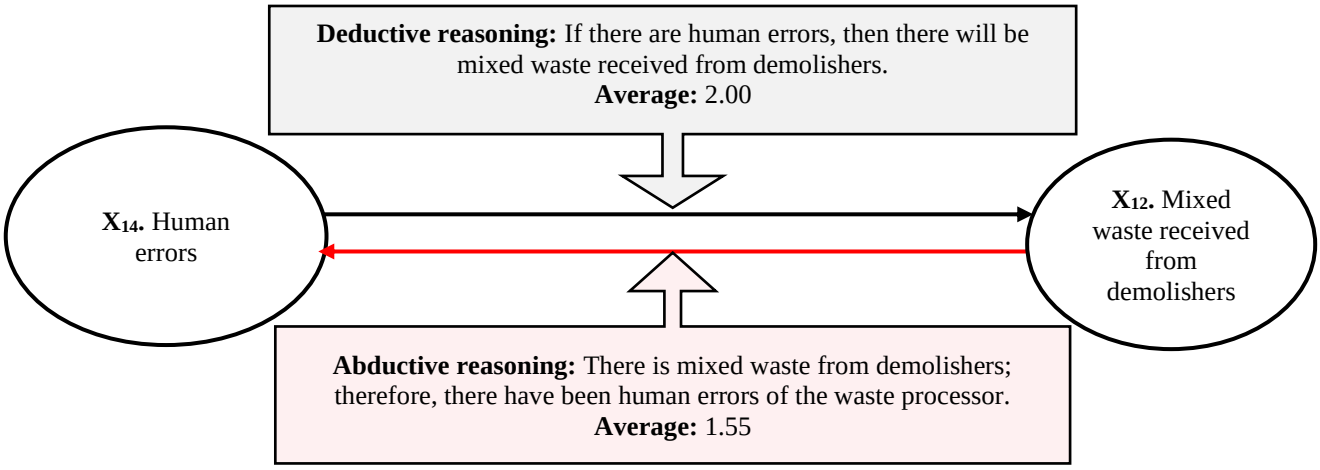


Figure 5.3D. Circular relationship between X_{14} and X_{12}

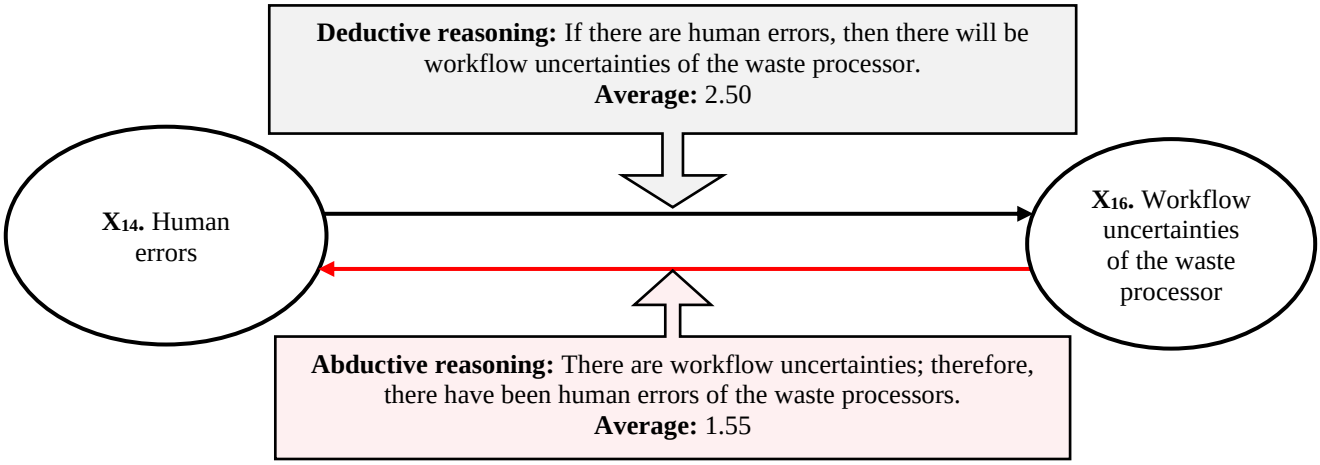


Figure 5.3E. Circular relationship between X_{14} and X_{16}



Figure 5.3. Eliminating circular relationships

As shown in Figure 5.3, the relationships with low average values were eliminated from the causal map as they were allied with abductive reasoning (see Jayasinghe 2019; Nadkarni & Shenoy 2004). For instance, in Figure 5.3A, the relationship from X_8 to X_7 does not imply that the demolisher's workflow uncertainties cause health and safety concerns. The reasoning in this causal statement is in the opposite direction to causation. Instead, the demolisher's health and safety concerns cause workflow uncertainties; thus, that relationship has received a higher average through deductive reasoning. Similarly, all the causal statements, including abductive reasoning, are

misrepresented by a link from effect to cause. All the relationships with abductive reasoning were considered redundant; thus, they were removed from the causal map. As a result, X_8-X_7, X_8-X_4, X_7-X_4, X_{12}-X_{14} and X_{16}-X_{14} relationships were removed from the causal map to develop the BBN-based model.

5.7.2 Distinguishing between direct and indirect relationships

The causal map in Figure 5.2 does not distinguish between 'direct' and 'indirect' relationships between nodes. According to the principles of the causal mapping approach, the direct relationships between variables in the causal map should be eliminated when there is an indirect relationship between them, despite those direct relationships were identified as most significant based on nine logical tests. As explained in Chapter 3, Subsection 3.5.2.2.2 (2), a clear understanding of the nature of relations between nodes could be obtained by removing direct relationships. Therefore, this section eliminates direct relationships from the causal map. The removed direct relationships are presented separately in the following sub-sections for the relationships between (i) epistemic uncertainties that lead to IPNs and (ii) IPMs and epistemic uncertainties that lead to IPNs.

5.7.2.1 Distinguishing direct and indirect relationships between epistemic uncertainties that lead to IPNs

Forty-four (44) direct relationships between epistemic uncertainties that lead to IPNs were identified for elimination in accordance with the principles of the causal mapping approach. The removed direct relationships between epistemic uncertainties are shown red arrows in Figure 5.4. For example, as shown in Figure 5.4, 'regulatory uncertainties of the demolisher (X_1)' is conditionally independent of 'contractual uncertainties from FSC-upstream actors (X_3)' given the 'incentivising uncertainties of the demolisher (X_2)'. According to the principle of conditional independence, even though the causal map connects regulatory uncertainties of the demolisher and contractual uncertainties from FSC-upstream actors, this link is unnecessary due to the presence of incentivising uncertainties of the demolisher. This emphasises that regulatory uncertainties of the demolisher affect contractual uncertainties only through incentivising uncertainties. Therefore, the arrow from regulatory uncertainties to contractual uncertainties from FSC-upstream actors is eliminated as it is redundant and it increases the model's complexity. Similarly, all the direct relationships between epistemic uncertainties, as

illustrated in Figure 5.4, were eliminated. These alterations reduced the cause-and-effect relationships between epistemic uncertainties from 69 to 18 relationships.

However, it is important to highlight that the removal of direct relationships is not always acceptable because all the time, the effect of one node on another node is not completely modelled by the effect of the first on a third mediating node (which in turn is a cause for the second node). Therefore, it is important to empirically validate the BBN-based conceptual model to confirm whether all the eliminated direct relationships are valid and reasonable (see Chapter 6).

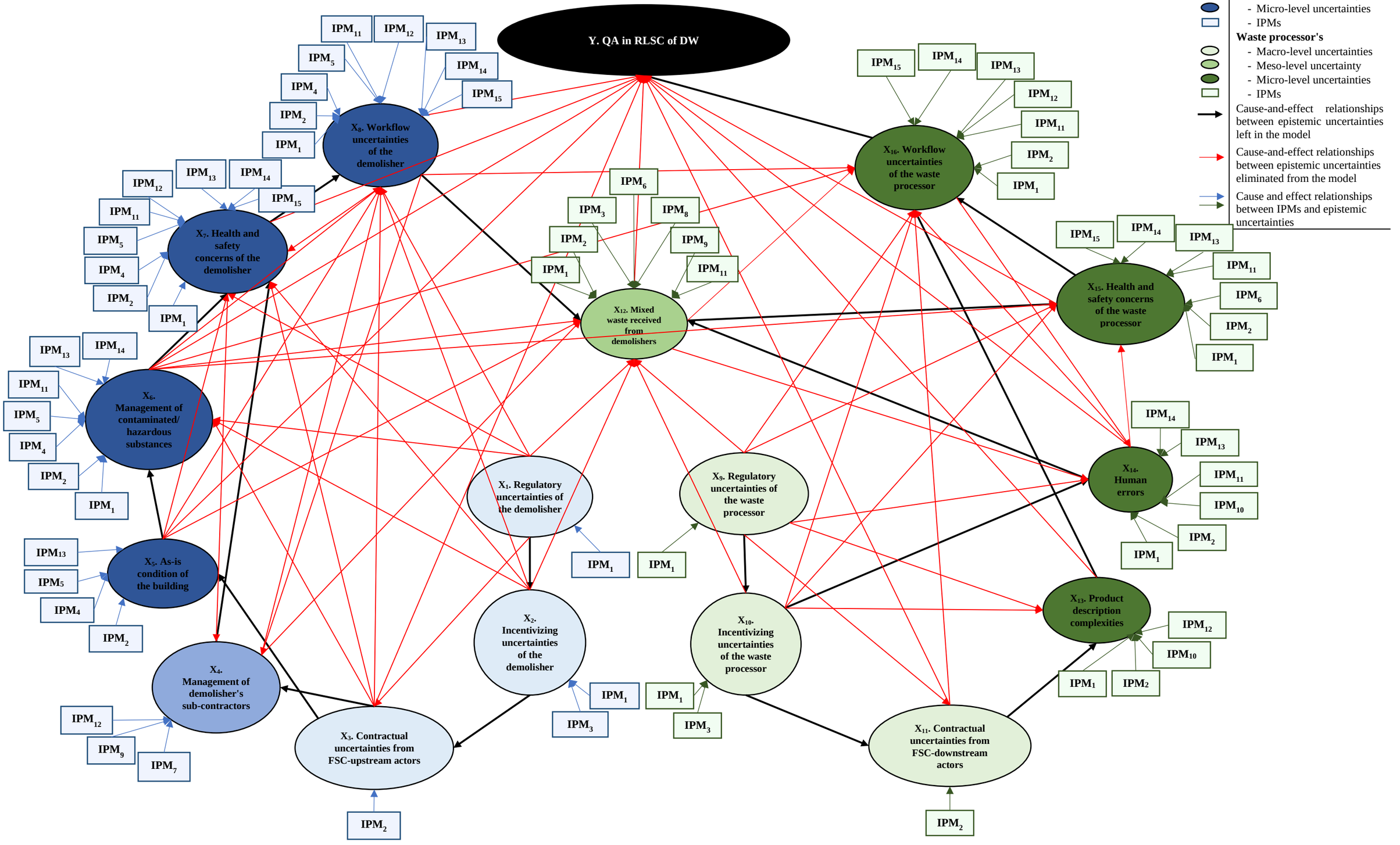


Figure 5.4. Distinguishing direct and indirect relationships between epistemic uncertainties

5.7.2.2 Distinguishing direct and indirect relationships between epistemic uncertainties that lead to IPNs and IPMs

In a similar way to how relationships between epistemic uncertainties were eliminated through distinguishing the direct and indirect relationships, redundant relationships between epistemic uncertainties and IPMs were also eliminated, complying with the conditional independence principle, as explained in Chapter 3, Subsection 3.5.2.2.2(b). Accordingly, 44 relationships between epistemic uncertainties and IPMs were identified for elimination from the causal map. All these removed relationships are illustrated in Figure 5.5.

In the causal map (see Figure 5.4), IPMs repeatedly appear appropriate for many epistemic uncertainties. However, depending on the relationships between epistemic uncertainty nodes (i.e., chance nodes), IPMs (i.e., decision nodes) do not need to appear repetitively. Given this point, IPMs should be linked to the most appropriate epistemic uncertainty, complying with the principles of the causal mapping approach. The impact of these IPMs could then be propagated through the attached epistemic uncertainty to the remaining directly and/or indirectly linked epistemic uncertainties. Therefore, if the same IPM was linked to two or more epistemic uncertainties with direct or indirect relationships, only the link between the IPM and root cause uncertainty needed to remain. For example, in Figure 5.5, 'rules and programs (IPM_1)' is an IPM that could be undertaken in response to the demolisher's epistemic uncertainties, such as 'regulatory uncertainties of the demolisher (X_1)'; 'incentivising uncertainties of the demolisher (X_2)'; 'management of contaminated/hazardous substances (X_6)'; 'health and safety concerns of the demolisher (X_7)'; and 'workflow uncertainties of the demolisher (X_8)'. However, even if the causal map shows the links from rules and programs to each above-mentioned epistemic uncertainty, according to the principles of the causal mapping approach, only the link to regulatory uncertainty is required to remain in the BBN-based conceptual model. Simply stated, this means that rules and programs indirectly impact on all other epistemic uncertainties by directly responding to regulatory uncertainties. Therefore, the arrows from 'rules and programs (IPM_1)' to the remaining epistemic uncertainties that lead to IPNs were eliminated as they are redundant and increase the complexity of the model's presentation. All redundant links in the causal map between IPMs and epistemic uncertainties that lead to IPNs were similarly eliminated, as shown in Figure 5.5.

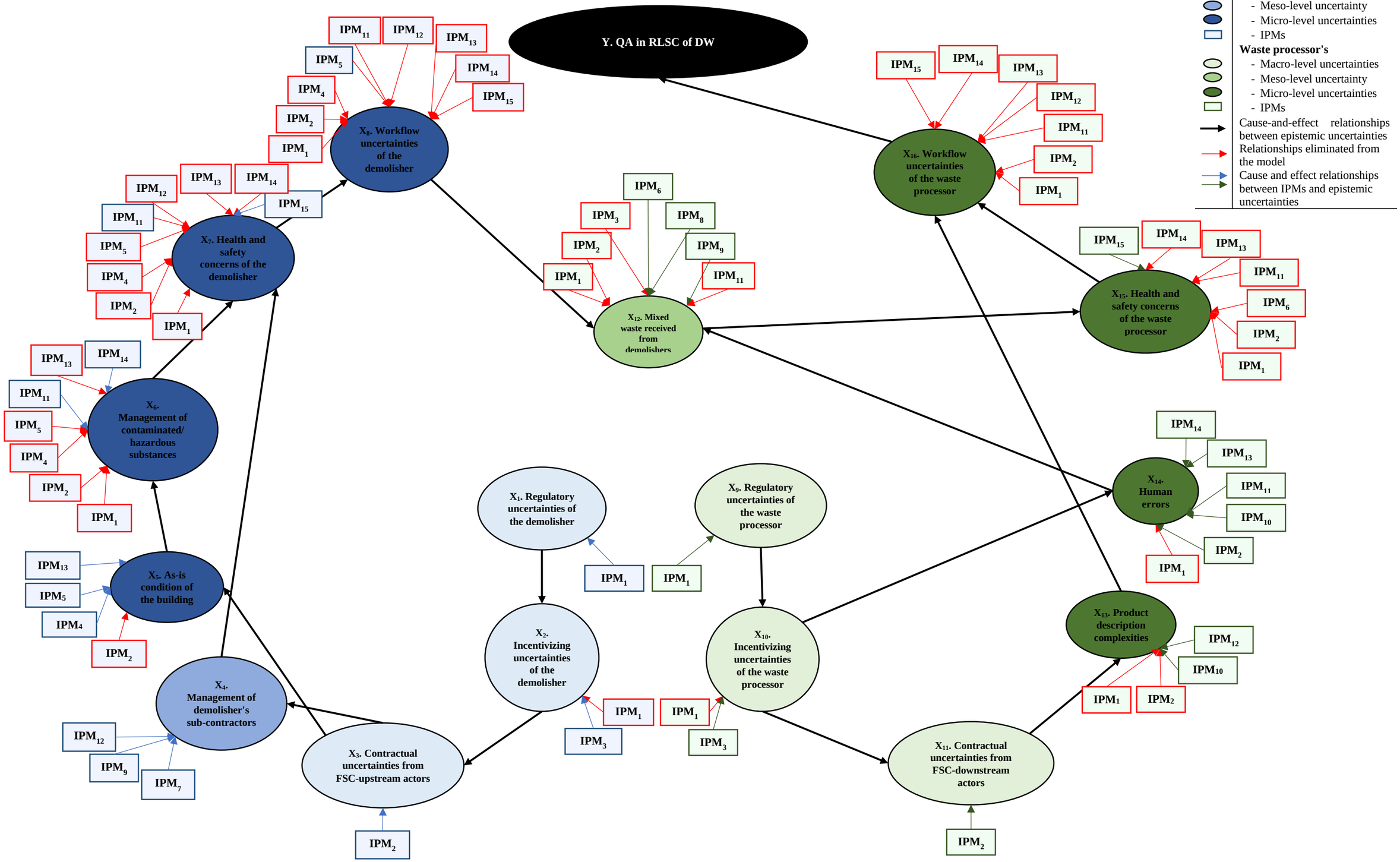


Figure 5.5. Causal map after eliminating redundant relationships

Accordingly, the cause-and-effect relationships between IPMs and epistemic uncertainties were reduced from 71 to 27. The next section discusses how the status quo arrangement of nodes and relationships in the causal map conforms to deductive reasoning underlying the cause-and-effect relationships.

5.7.3 Deductive reasoning underlying cause-and-effect relationships

As explained in Chapter 2, Subsection 2.5.2.2.2(c), to be a BBN-based conceptual model, the foundation of the causal map must be the deductive reasoning underlying the direction of causation. The map represents the different levels of epistemic uncertainties of each of the demolisher and waste processor using blue and green ovals, respectively. As shown on this causal map, all epistemic uncertainties are arranged in the direction of causation, that is, from cause to effect. The macro-level uncertainties are positioned at the bottom of the model. They are then propagated through meso-level and micro-level uncertainties to QA in RLSCs of DW, as shown in Figure 5.6. 'Regulatory uncertainties' are the root causes of other epistemic uncertainties for both the demolisher and waste processor. When considering macro-level uncertainties on their own, regulatory uncertainties cause incentivising uncertainties and, thereby, contractual uncertainties. Notably, this arrangement is similar in the case of both demolisher and waste processor. The causal map also indicates that cause-and-effect relationships between epistemic uncertainties are aligned with operational and materials flows of RLSCs of DW, as explained in Chapter 2, Section 2.3. As shown in Figure 5.6, the demolisher's epistemic uncertainties are propagated through macro-level uncertainties to meso- and micro-level uncertainties and then connect with the waste processor's epistemic uncertainties through 'mixed waste received from demolishers (X_{12})'. The micro-level uncertainties also appear in the sequence of operations undertaken at each phase of RLSCs of DW. For example, from the demolisher's perspective, the four micro-level uncertainties are positioned in the sequence of operations undertaken in the building dismantling and on-site processing phase. As illustrated in Figures 5.7 and 5.8 (shown in dotted arrows), even if the waste processor's workflow uncertainties directly affect QA, the demolisher's epistemic uncertainties exert only an indirect influence on QA in RLSCs of DW.

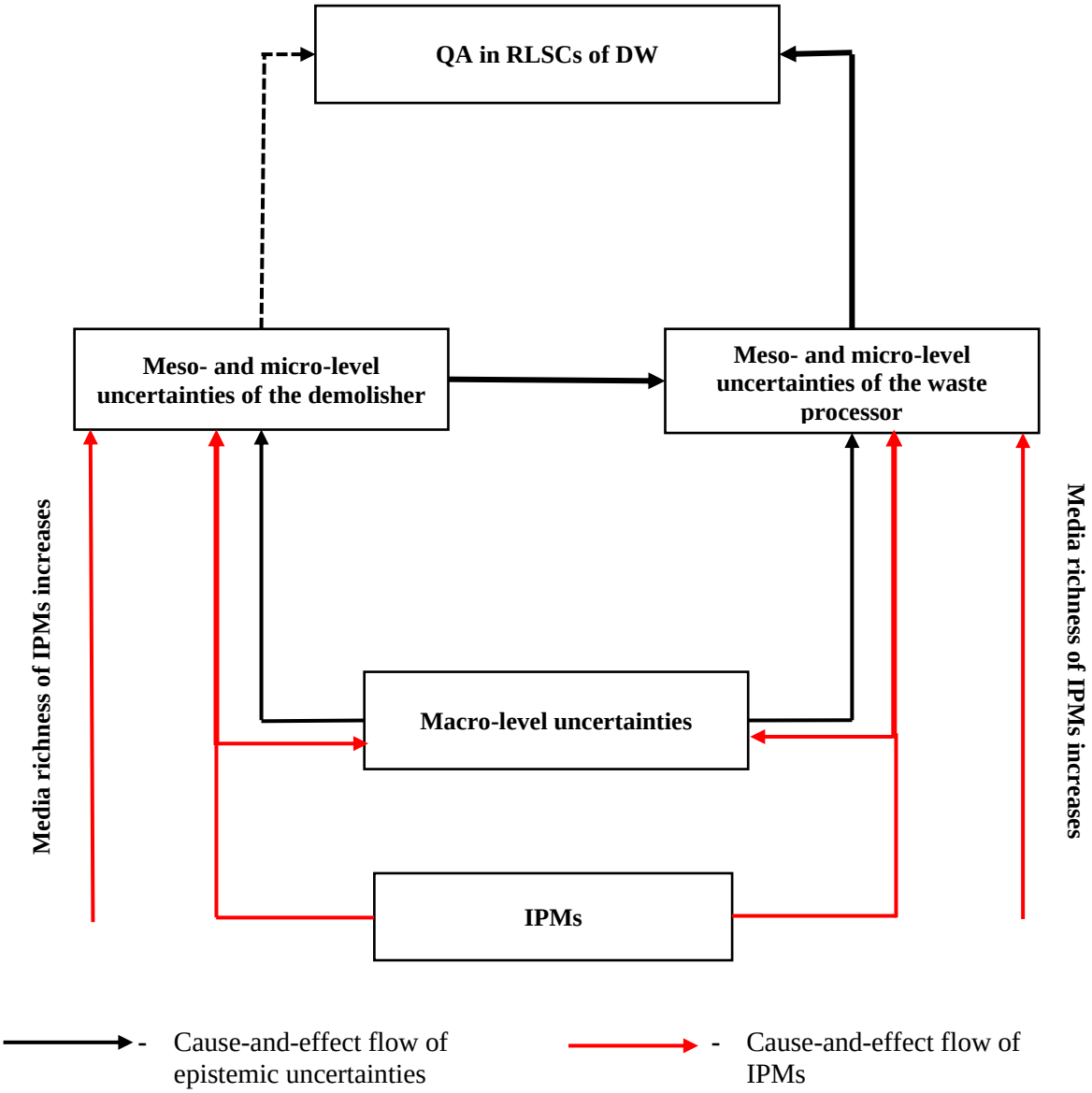


Figure 5.6. Deductive reasoning underlying cause-and-effect relationships

All IPMs are also positioned to address the most appropriate epistemic uncertainties, conforming to deductive reasoning. As explained in Chapter 2, Section 2.5, the mechanisms that process less-rich information have appeared at the bottom level to respond to macro-level uncertainties. For instance, less-rich IPMs such as 'rules and programs (IPM_1)' and 'planning and goal setting (IPM_2)' are positioned to respond to macro-level uncertainties which occur due to external factors not under the control of internal RLSC stakeholders. On the other hand, most mechanisms that process rich information respond to epistemic uncertainties at the top of the causal map. Therefore, IPMs that provide rich information respond to meso- and micro-level uncertainties under the control of the demolisher and waste processor. It is also observable from the

causal map that the media richness of IPMs appearing from the bottom to the top of the model increases when epistemic uncertainties are propagated from macro-level uncertainties to meso and micro-level uncertainties, as shown in Figure 5.6. It is evident that the causal map consists of logical relationships under deductive reasoning; thus, it has been successfully converted into a BBN-based conceptual model.

5.8 BBN-based Conceptual Information Processing Model

Once all alterations were made to the causal map, the BBN-based conceptual model was developed using GeNIe 3.0, as illustrated in Figure 5.7. Accordingly, the model consists of six macro-level uncertainties, two meso-level uncertainties and eight micro-level uncertainties. The model also includes 16 IPMs employed by demolishers and waste processors in response to epistemic uncertainties. As shown in Figure 5.7, the BBN-based model indicates epistemic uncertainties as chance nodes, IPMs as decision nodes and the performance measurement criterion (i.e., QA in RLSCs of DW) as the objective node (indicated as a hexagon) (see Chapter 3, Subsection 3.5.2.2.2). Many redundant cause-and-effect relationships were eliminated from the causal map when transforming it into the BBN-based conceptual model, complying with the principles of the causal mapping approach (see Section 5.7). Accordingly, the cause-and-effect relationships between epistemic uncertainties were reduced from 69 to 18, and the relationships between IPMs and epistemic uncertainties were reduced from 71 to 24. Similar to the causal map, the BBN-based conceptual model has two independent parent nodes: 'regulatory uncertainties of the demolisher (X_1)' and 'regulatory uncertainties of the waste processor (X_9)'. All the remaining epistemic uncertainties appear as child nodes that depend upon one another.

As shown in Figure 5.7, the BBN-based conceptual model separately outlines the epistemic uncertainties of the demolisher (blue ovals) and the waste processor (green ovals). When considering the demolisher's side, all the macro-level uncertainties are propagated through the meso-level and micro-level uncertainties to 'workflow uncertainties of the demolisher (X_8)'. Then, 'workflow uncertainties of the demolisher (X_8)' leads to 'mixed waste received from demolishers (X_{12})' which is the meso-level uncertainty of the waste processor. The 'mixed waste received from demolishers (X_{12})' is the epistemic uncertainty that links the demolisher's and waste processor's uncertainties. Similar to the demolisher's arrangement, the waste processor's epistemic

uncertainties start with regulatory uncertainties (X_9). This is then propagated through other macro-, meso- and micro-level uncertainties to 'workflow uncertainties of the waste processor (X_{16})'. Unlike the causal map, the BBN-based conceptual model has only one chance node, that is, 'workflow uncertainties of the waste processor (X_{16})' which is directly linked to Y. QA in RLSCs of DW.

Compared with the causal map, the BBN-based model includes only a minimum number of IPMs, linked with epistemic uncertainties. In the causal map (see Figure 5.2), many IPMs appear in response to epistemic uncertainties at the top rather than the bottom of the model. On the other hand, in the BBN-based conceptual model (see Figure 5.7), a few IPMs appear in response to epistemic uncertainties at the top and bottom of the model on each side of the demolisher and waste processor. Even if the highest number of IPMs were available for workflow uncertainties in the causal map, none would be included in the BBN-based model. In the BBN-based model, the highest number of IPMs could be found in response to the meso- and micro-level uncertainties at the model's intermediate level on both sides of the demolisher and waste processor. Of all IPMs, the highest number (i.e., five IPMs) appeared in response to 'human errors (X_{14})', a micro-level uncertainty of waste processors. In the BBN-based model, IPMs are arranged as their media richness increases from the bottom to the top. For instance, formal and less-interactive IPMs, such as rules and programs that provide a known response to problems, appear in response to epistemic uncertainties at the bottom of the model, with these beyond the control of internal stakeholders. The intermediate-level uncertainties, including meso- and micro-level uncertainties, are more within the control of internal stakeholders than the bottom-level macro-level uncertainties. Therefore, the number of IPMs and their media richness increase with epistemic uncertainties from the bottom to the intermediate level of the model. For example, as shown in Figure 5.7, three IPMs appear in response to the ''as-is' condition of the building (X_5)', with this more manageable for the demolisher than 'regulatory uncertainties (X_1)'. However, after the increase in the number of IPMs, as the IPMs' effect on one epistemic uncertainty impacts on the subsequent remaining uncertainties, at one point, the number of IPMs again reduces on both the demolisher's side and the waste processor's side. For instance, after employing the optimal number of IPMs in response to intermediate-level epistemic uncertainties, internal stakeholders are left with only the creation of slack resources (IPM_{15}) to undertake in response to the most critical top-level uncertainties,

such as health and safety concerns. Therefore, undertaking many effective IPMs in response to epistemic uncertainties that appear at the root cause level is recommended to avoid the occurrence of subsequent uncertainties. However, this would not be workable if these epistemic uncertainties were caused by reasons beyond the control of internal RLSC stakeholders.

The status quo representation of the BBN-based conceptual model (see Figure 5.7) is comparatively simpler and more manageable than the causal map; thus, probability elicitation would be feasible. However, as explained in Chapter 3, Subsection 3.5.2.2.2, removing redundant relationships based on the causal mapping approach principles is not always acceptable as some relationships could be present in the model based on the real-world context. Therefore, it is crucial to empirically validate the BBN-based conceptual model before presenting it for probability elicitation to confirm that all the existing relationships are valid and reasonable (see Chapter 6).

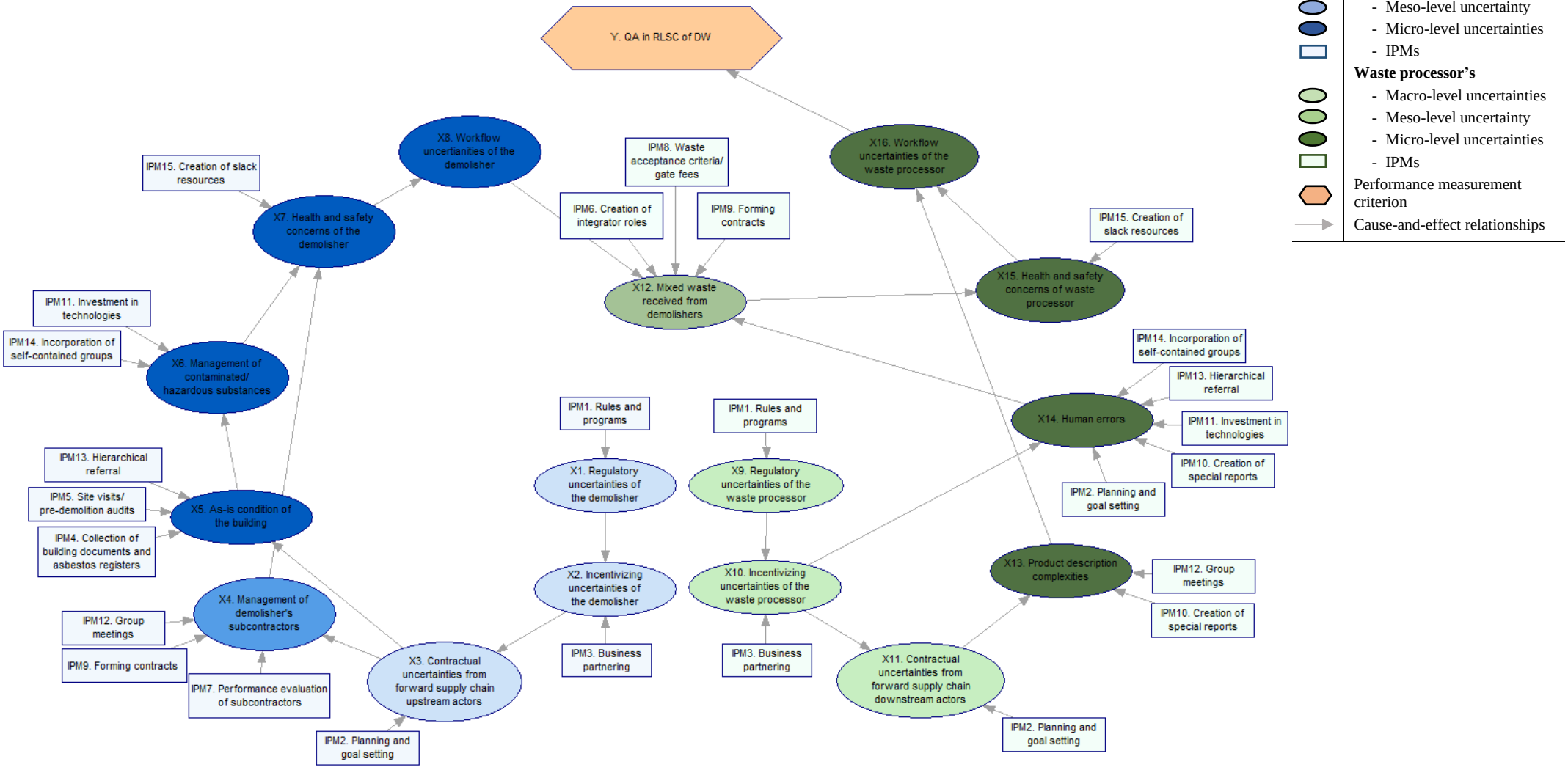


Figure 5.7. BBN-based conceptual information processing model

5.9 Concluding Remarks

This chapter presented the analysis of the cause-and-effect relationships and the development of the BBN-based conceptual model using the causal map. As the first step, the causal map was developed in two stages. In the first stage, the causal map was developed with the pair-wise comparisons of uncertainty–uncertainty and uncertainty–performance measurement criteria. The causal map was then further developed in the second stage using cause-and-effect relationships between IPMs and epistemic uncertainties. At the end of these two stages, a causal map was developed, comprising 140 cause-and-effect relationships between (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and QA in RLSCs of DW' and (iii) IPMs and epistemic uncertainties. This map consisted of two root cause epistemic uncertainties and 11 uncertainties with direct relationships with QA in RSLCs of DW. Due to the complexity of the causal map, in the next step, it was transformed into a BBN-based conceptual model using the principles of the causal mapping approach. After this transformation, the cause-and-effect relationships in the BBN-based model were reduced to 45 relationships; thus, it is manageable for the introduction of probability elicitation. However, before applying the model in the real-world context, it needed to be empirically validated, as discussed in the next chapter.

6 Empirical Validation of Bayesian Belief Network (BBN)-based Conceptual Information Processing Model for Quality Assurance

6.1 Introduction

Chapter 5 developed the BBN-based conceptual information processing model for QA in RLSCs of DW. This model consists of cause-and-effect relationships between (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and QA in RLSCs of DW; and (iii) IPMs and epistemic uncertainties. Even if this BBN-based model was practically feasible for analysing epistemic uncertainties, it would still need to be validated empirically to confirm whether the right model, with all its relationships, has been built, before its introduction to probability elicitation. Therefore, this chapter describes the empirical validation of the model through a focus group discussion. In this validation process, the status quo representation of the BBN-based conceptual model was introduced to a group of experts in this area of study to review, refine and make the alterations necessary for it to be applicable to the real-world context of RLSCs of DW. The findings of this empirical validation are presented in the following sections.

6.2 Demographic Information of Participants: Focus Group Discussion

The focus group discussion was conducted to validate the BBN-based conceptual information processing model for QA developed based on the principles of the causal mapping approach. In this focus group discussion, five experts were asked to evaluate the model according to the context of QA in RLSCs of DW. The following basic questions were asked during the focus group discussion (see Appendix 3[c]):

1 What additions and deductions do you suggest for the relationships in the existing model as per the context of RLSCs of DW?
Relationships between epistemic uncertainties that lead to IPNs

Relationships between epistemic uncertainties and QA in RLSCs of DW
Relationships between IPMs and epistemic uncertainties.

2 What is your overall assessment of the refined model in terms of the impact on QA in RLSCs of DW?

The five experts involved in the focus group discussion were from the South Australian DW management sector. The purposive sampling technique was used to select these participants, as explained in Chapter 3, Subsection 3.5.1.3. Three of the five participants represented the off-site waste processing phase in RLSCs of DW, while the remaining two represented the building dismantling and on-site waste processing phase. Notably, one participant currently engaged in the off-site waste processing phase had previous experience in the building dismantling and on-site processing phase. Given their extensive engagement in the industry, most participants had known each other before participating in the focus group discussion. This group's main strength was that all participants had more than 10 years of experience and held senior designations in their respective organisations. The mean experience of participants was nearly 17 years. The profile of focus group participants is presented in Table 6.1.

Table 6.1. Profile of focus group participants

Participant code	Designation	Years of experience	CDW management subsector
FGP1	Environmental Officer	21	Off-site waste processing and building dismantling, and on-site waste processing
FGP2	Accounts Manager	13	Off-site waste processing
FGP3	Operations Manager	13	Off-site waste processing
FGP4	Managing Director	28	Building dismantling and on-site processing
FGP5	Human Resource and Occupational Health and Safety Manager	11	Building dismantling and on-site processing

6.3 Findings of the Focus Group Discussion

The expert participants in the focus group were provided with the status quo presentation of the BBN-based conceptual information processing model for QA (see Chapter 5, Figure 5.7), along with an explanation of the process followed to obtain the model and the purpose for its development. They were then asked to point out the alterations needed so the existing model would reflect the RLSCs of DW context.

6.3.1 Additions to the BBN-based model

On examining the status quo presentation of the BBN-based conceptual model, as shown in Chapter 5, Figure 5.7, the experts agreed to add 15 additional cause-and-effect relationships to the model, as per the RLSCs of DW context. The following subsections outline these newly added relationships and provide the experts' justifications.

6.3.1.1 Direct relationship between 'regulatory uncertainties of the demolisher (X_1)' and 'contractual uncertainties from FSC-upstream actors (X_3)'

After examining the model, all expert participants agreed to insert a direct relationship between 'regulatory uncertainties of the demolisher (X_1)' and 'contractual uncertainties from FSC-upstream actors (X_3)'. Participant FGP4 stated that the contractor/developer/ client only needs the demolition job to be done quickly with a minimum cost. For this reason, they do not advocate for or encourage demolishers to engage in waste management. Participant FGP4 confirmed that one reason for this is the lack of state and local government incentives, as shown in the BBN-based conceptual model. However, the most persuasive cause was the unavailability of regulatory provisions for waste management on demolition sites. Participant FGP4 elaborated on this as follows.

> Most councils and the government are quiet. They do not provide incentives to encourage developers to consider the waste management aspect of the demolition; that is true. But, most importantly, there is no regulatory provision for that. Particularly, suppose the client or developer gets the regulatory obligation from the government to manage waste on the site. In that case, they'll take appropriate measures to ensure that the demolition guys are doing the right [thing] at the site.

Participant FGP5 mentioned that, as no strict regulatory intervention exists for demolition, contractual uncertainty could even be found in government demolition jobs. Participant FGP5 shared one of his contractual uncertainty experiences encountered in a government-funded demolition project:

> What they're doing [at] Magill right at the moment. They're going to knock down 20 or 30 houses. And now a demolition company is going to go in, and they've got

> 10 days to do the job, but the houses have been there for three months and then just go in, smash everything, all in the landfill, timber, brick, stone, glass, plastic, everything.

With the support of these statements, as shown in Figure 6.1, a new direct relationship was added between 'regulatory uncertainties of the demolisher' and 'contractual uncertainties from FSC-upstream actors' (X_1-X_3), as well as their indirect relationship through 'incentivising uncertainties of the demolisher (X_2)'.

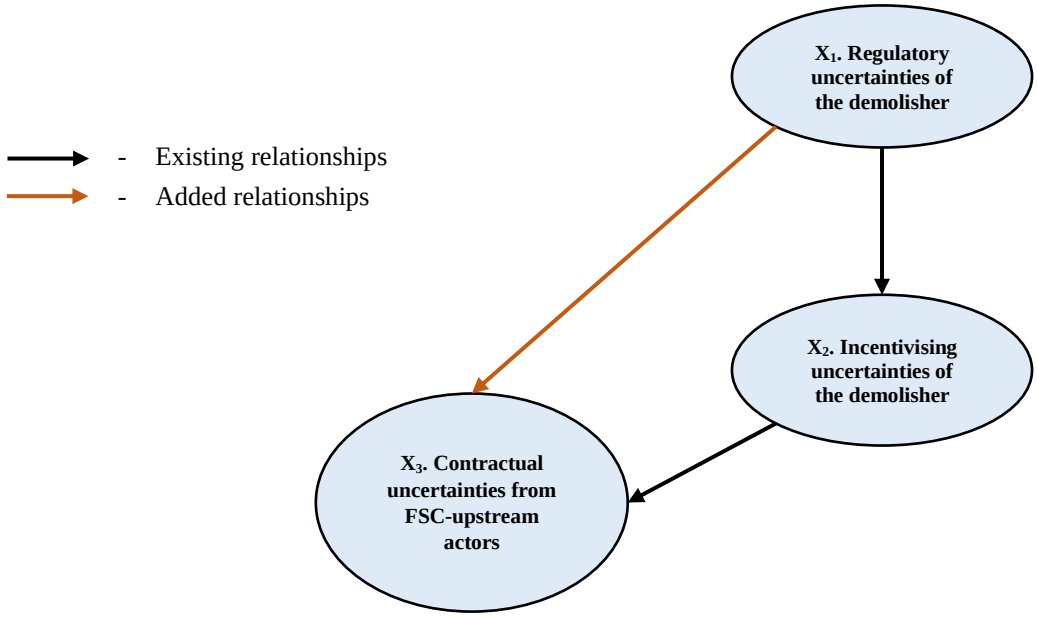


Figure 6.1. Added direct relationship between X_1 and X_3

6.3.1.2 Direct relationship between 'management of demolisher's sub-contractors (X_4)' and 'workflow uncertainties of the demolisher (X_8)'

The expert participants confirmed the existing indirect relationship between 'management of demolisher's sub-contractors (X_4)' and 'workflow uncertainties of the demolisher (X_8)' through 'health and safety concerns of the demolisher (X_7)', as shown in Figure 6.2. Participant FGP3 mentioned that sub-contractors were an asset for demolishers as they had no certainty regarding having jobs every day. With the employment of many sub-contractors, the planning and coordination between them is a challenge for the demolisher, especially due to the strict time constraints in dismantling jobs. As a result, the demolisher faces a threat to sub-contractors' health and safety. Participant FGP3 emphasised that if health and safety are facing a threat, the entire workflow could be disrupted and will not be completed as planned.

Even though the indirect relationship was identified, participants highlighted that a direct relationship should exist between X_4 and X_8. Participant FGP1 explained that the

difficulty of managing sub-contractors does not always affect workflow by creating health and safety concerns. Instead, mostly in the practical context, it directly impacts on the demolisher's workflow. Participant FGP1 explained this in detail as follows:

> In a demolition job, first, the asbestos is removed before starting the soft stripping. Usually, for soft stripping, we allocate a day or two. If we are unable to coordinate, plan, or any unexpected circumstance occurs, all these operations lag.

Consequently, a new direct relationship between 'management of demolisher's sub-contractors (X_4)' and 'workflow uncertainties of the demolisher (X_8)' was added to the model, as shown in Figure 6.2.

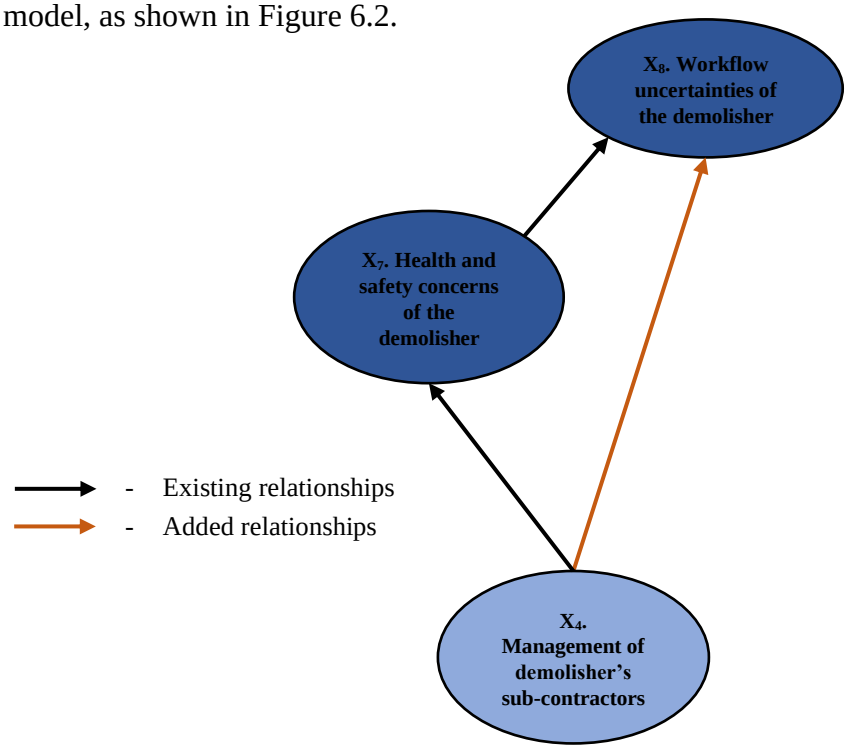


Figure 6.2. Added direct relationship between X_4 and X_8

6.3.1.3 Direct relationship between ''as-is' condition of the building (X_5)' and 'health and safety concerns of the demolisher (X_7)'

All participants agreed to insert a direct relationship between ''as-is' condition of the building (X_5)' and 'health and safety concerns of the demolisher (X_7)', in addition to the existing indirect relationship between them via 'management of contaminated/ hazardous substances (X_6)', as shown in Figure 6.3.

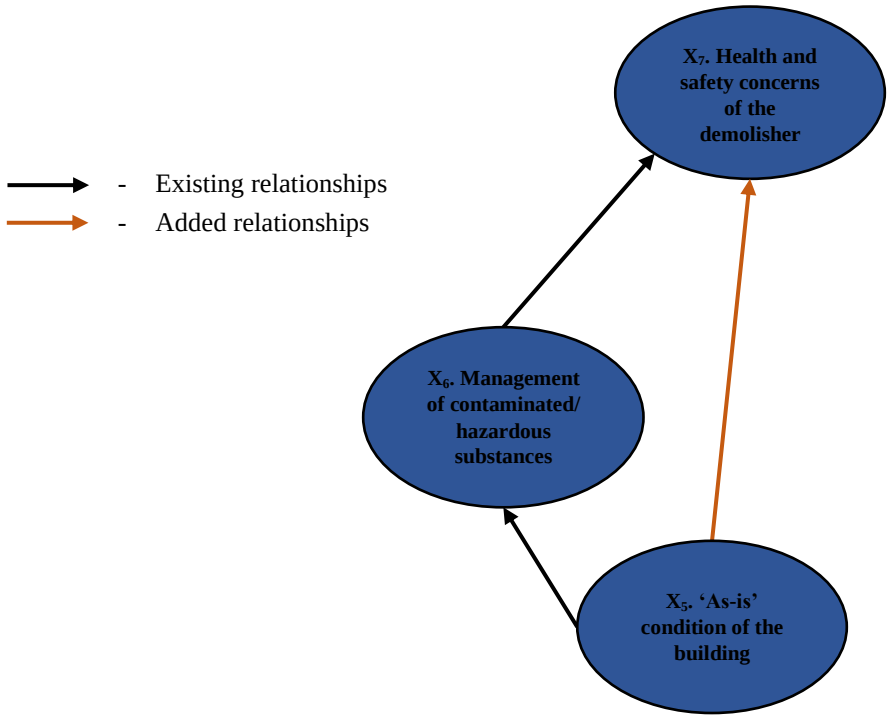


Figure 6.3. Added direct relationship between X_5 and X_7

All participants agreed that the indirect relationship of X_5-X_6-X_7 in the existing model was clear (see Chapter 5, Figure 5.7). Participant FGP5 revealed how critical it is to ascertain the 'as-is' condition of the building before demolition:

> So, basically, we go out there and survey the house to make sure of the scope and what it contains. Sometimes you can tell there are patent numbers on the back of the asbestos, so we know when it was manufactured, and we know it's asbestos. But sometimes, we took a piece and tested it to make sure it was asbestos.

Participant FGP5 emphasised that if the 'as-is' condition of the building is not properly understood and elucidated before demolition, the management of contaminated/ hazardous substances and, thereby, of health and safety will become uncertain for the demolisher. Participant FGP5 further highlighted that the 'as-is' condition of the building directly impacts on the demolisher's health and safety concerns, even if no uncertainty is present in managing contaminated/hazardous substances:

> … if not, there could be many dangers. Because we're knocking the building down, and the wall could fall on someone's adjoining property, on someone's house, on their fence, on someone's car or a pedestrian; presumably, we've got many to consider and eliminate.

Therefore, a direct relationship between the ''as-is' condition of the building (X_5)' and 'health and safety concerns of the demolisher (X_7)' were added to the model.

6.3.1.4 Direct relationship between 'management of contaminated/hazardous substances (X_6)' and 'workflow uncertainties of the demolisher (X_8)'

All participants agreed that a relationship existed between 'management of contaminated/hazardous substances (X_6)' and 'workflow uncertainties of the demolisher (X_8)' via 'health and safety concerns of the demolisher (X_7)', as shown in Figure 6.4. Participant FGP4 explained this as follows:

> Of course, if there are unrecognised contaminated or hazardous substances, obviously, there could be a high risk for health and safety. That's why we are making a lot of effort to identify them before starting the project. If there are threats to health and safety, we can't proceed anymore because it is not legal.

Participants also recommended inserting a direct link between 'management of contaminated/hazardous substances (X_6)' and 'workflow uncertainties of the demolisher (X_8)'. Participant FGP1 argued that the inability to distinguish contaminated/hazardous substances disrupts the entire demolition process:

> Once I could remember, a house was there to be demolished at Newton without an updated asbestos register. We tried and surveyed a lot to understand the asbestos present in this house before starting the demolition. We asked the stripper to come while doing the job and found the roof cavity insulation contained asbestos. We checked it, and yes, it was there; that job was delayed.

Therefore, a direct relationship is found between 'management of contaminated/ hazardous substances (X_6)' and 'workflow uncertainties of the demolisher (X_8)', as well as their indirect relationship through 'health and safety concerns of the demolisher (X_7)'. Thus, this new relationship was added to the BBN-based conceptual model:

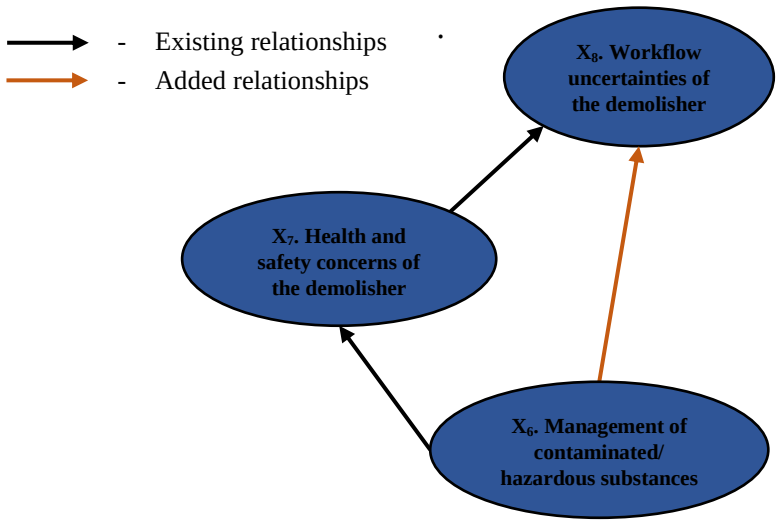


Figure 6.4. Added direct relationship between X_6 and X_8

6.3.1.5 Direct relationship between 'regulatory uncertainties of the demolisher (X_1)' and 'management of contaminated/hazardous substances (X_6)'

Participant FGP4 suggested adding a link between 'regulatory uncertainties of the demolisher (X_1)' and 'management of contaminated/hazardous substances (X_6)', with the agreement of all participants. This new relationship created a direct cause-and-effect relationship between X_1 and X_6, as well as their indirect relationship through two routes, as shown in Figure 6.5.

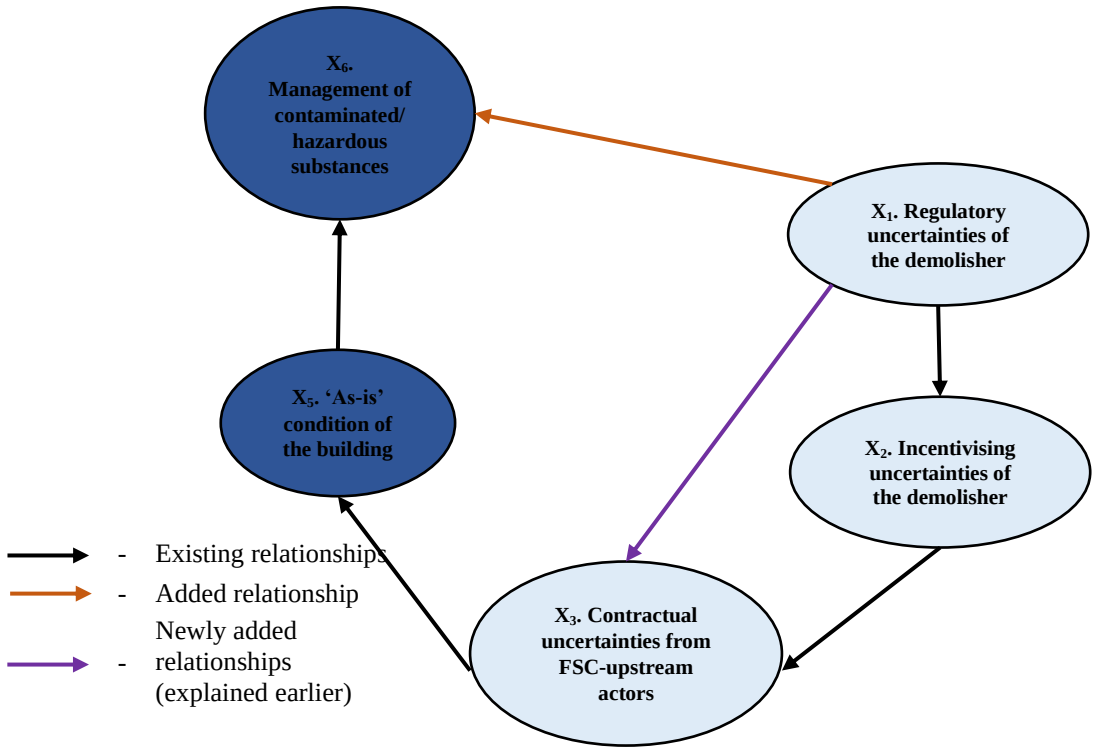


Figure 6.5. Added direct relationship between X_1 and X_6

Participants agreed that 'regulatory uncertainties of the demolisher (X_1)' directly and indirectly cause 'contractual uncertainties (X_3)' through 'incentivising uncertainties (X_2)', as explained in Subsection 6.3.1.1. When the necessary building information, such as as-built drawings and asbestos registers, is not provided for the demolisher via a contract (i.e., 'contractual uncertainties from the FSC-upstream actors [X_3]'), the ''as-is' condition of the building (X_5)' and thereby, the 'management of contaminated/ hazardous substances (X_6)' become uncertain. Participants claimed that, in addition to these indirect relationships, 'regulatory uncertainties (X_1)' could directly lead to 'management of contaminated/hazardous substances (X_6)', even if the ''as-is' condition of the building (X_5)' was well ascertained. Confirming this argument, Participant FGP5 stated:

> There are codes of practice for safely removing non-friable asbestos and rock wool. Have a look at both these standard documents. I can tell you there's no difference in what you have to do in the two cases. But you will understand that non-friable asbestos is safer than removing rock wool. However, the code of practice to remove rock wool is the same. Absolutely pathetic.

Corresponding to this suggestion, a new relationship between 'regulatory uncertainties of the demolisher (X_1)' and 'management of contaminated/hazardous substances (X_6)' was added to the BBN-based conceptual model, as shown in Figure 6.5.

6.3.1.6 Direct relationship between 'contractual uncertainties from FSC-upstream actors (X_3)' and 'workflow uncertainties of the demolisher (X_8)'

The focus group participants suggested adding a direct relationship between 'contractual uncertainties from FSC-upstream actors (X_3)' and 'workflow uncertainties of the demolisher (X_8)', irrespective of their indirect relationships, as shown in Figure 6.6.

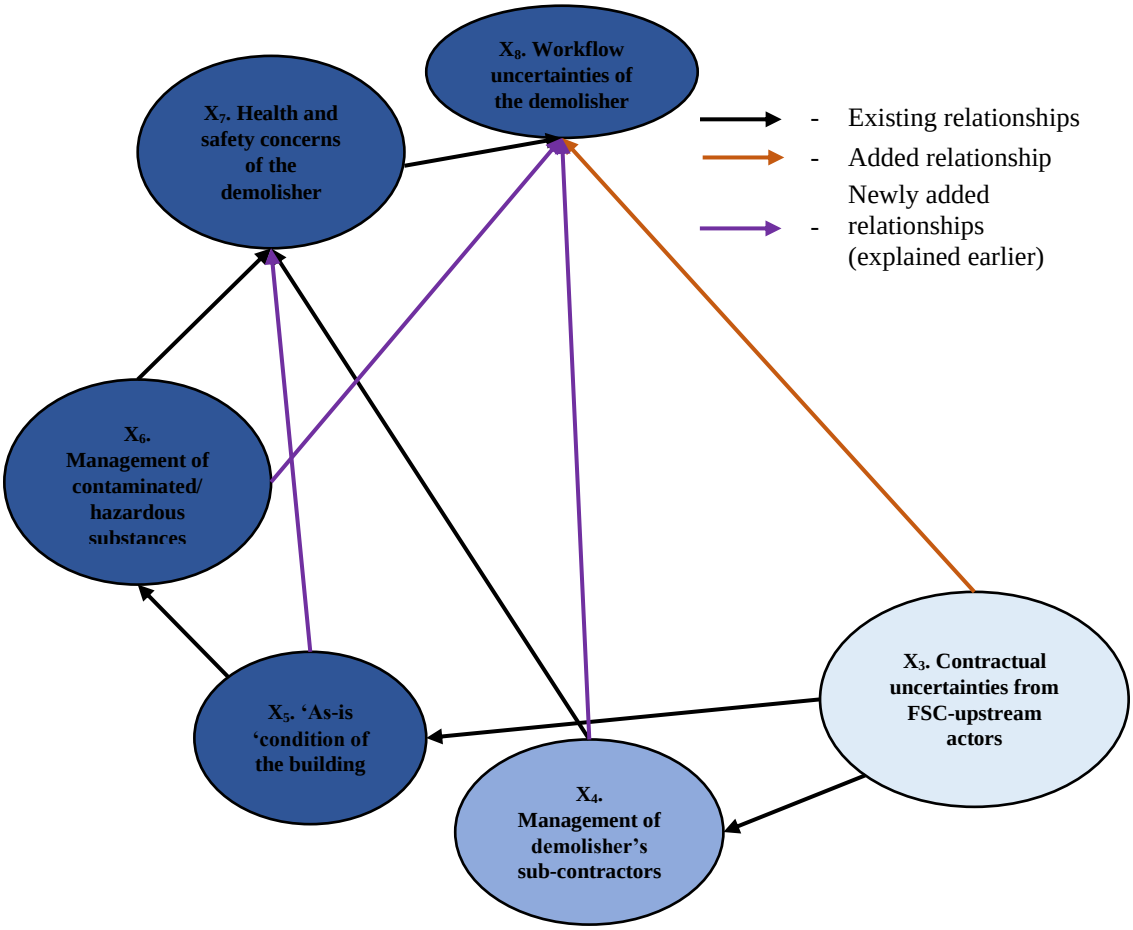


Figure 6.6. Added direct relationship between X_3 and X_8

All participants agreed that contractual uncertainties (X_3) made the management of sub-contractors (X_4) difficult and, thereby, exerted health and safety concerns on the demolisher (X_7). Participant FGP4 explained this in detail as follows:

> If the demolishing contract contradicts certain aspects of the job, it will be challenging to manage sub-contractors. For example, if there is a time constraint, the sub-contractors do not have sufficient time to get involved and do what they asked for, like stripping, asbestos removal, etc. In this case, obviously, there is a threat to health and safety.

As explained in Subsection 6.3.1.2, 'health and safety concerns (X_7)' cause 'workflow uncertainties of the demolisher (X_8)'. Therefore, the indirect relationship between X_3 and X_8 through X_4 and X_7 is admissible. As in Subsection 6.3.1.2, participants also established that a direct relationship was needed between X_4 and X_8. Given this point, the X_3-X_4-X_8 link was also acceptable. Following Subsections 6.3.1.3, 6.3.1.4 and 6.3.1.5, participants also confirmed the indirect relationship between X_3 and X_8 via the remaining routes, as shown in Figure 6.6.

In addition to the above indirect relationships, participants pointed out that a direct relationship should be established between X_3 and X_8:

> Our demolition contracts are fairly similar for everyone. Actually, it is quite similar to the sub-contract for concrete work or reinforcement or something like that. So certain conditions will be around. They'll specify how long we've given for the job; we just get asbestos information, STC2 (i.e., a check-off list to make sure that the power and utilities are disconnected) and drawings with boundary lines where we go, and they will tell us what we can knock down, what we can't. Apart from that, no single provision around preferred demolition procedure, requirements [for] source separation and waste management. (Participant FG5)

Given this explanation, Participant FGP5 emphasised that, in addition to indirect relationships between 'contractual uncertainties from the FSC-upstream actors (X_3)' and 'workflow uncertainties of the demolisher (X_8)', a direct relationship between them should be incorporated into the final model, as shown in Figure 6.6.

6.3.1.7 Direct relationship between 'regulatory uncertainties of the demolisher (X_1)' and 'workflow uncertainties of the demolisher (X_8)'

As stated in Subsections 6.3.1.1, 6.3.1.3, 6.3.1.4, 6.3.1.5 and 6.3.1.6, participants confirmed the relationships between epistemic uncertainties, as indicated in purple arrows in Figure 6.7. In all these relationships, multiple routes for epistemic uncertainties exist which form indirect relationships between 'regulatory uncertainties of the demolisher (X_1)' and 'workflow uncertainties of the demolisher (X_6)' (see

Figure 6.7). Even though these indirect relationships were established, participants also noted the need for a direct relationship between these two epistemic uncertainties (i.e., X_1 and X_8):

> None of the existing regulatory instruments mention the procedure to follow when deconstructing a building and on-site separation. Simply, there is no appropriate regulatory instrument to mandate those. (Participant FGP4)

With this suggestion, a direct relationship between 'regulatory uncertainties of the demolisher (X_1)' and 'workflow uncertainties of the demolisher (X_8)' was incorporated into the BBN-based conceptual model.

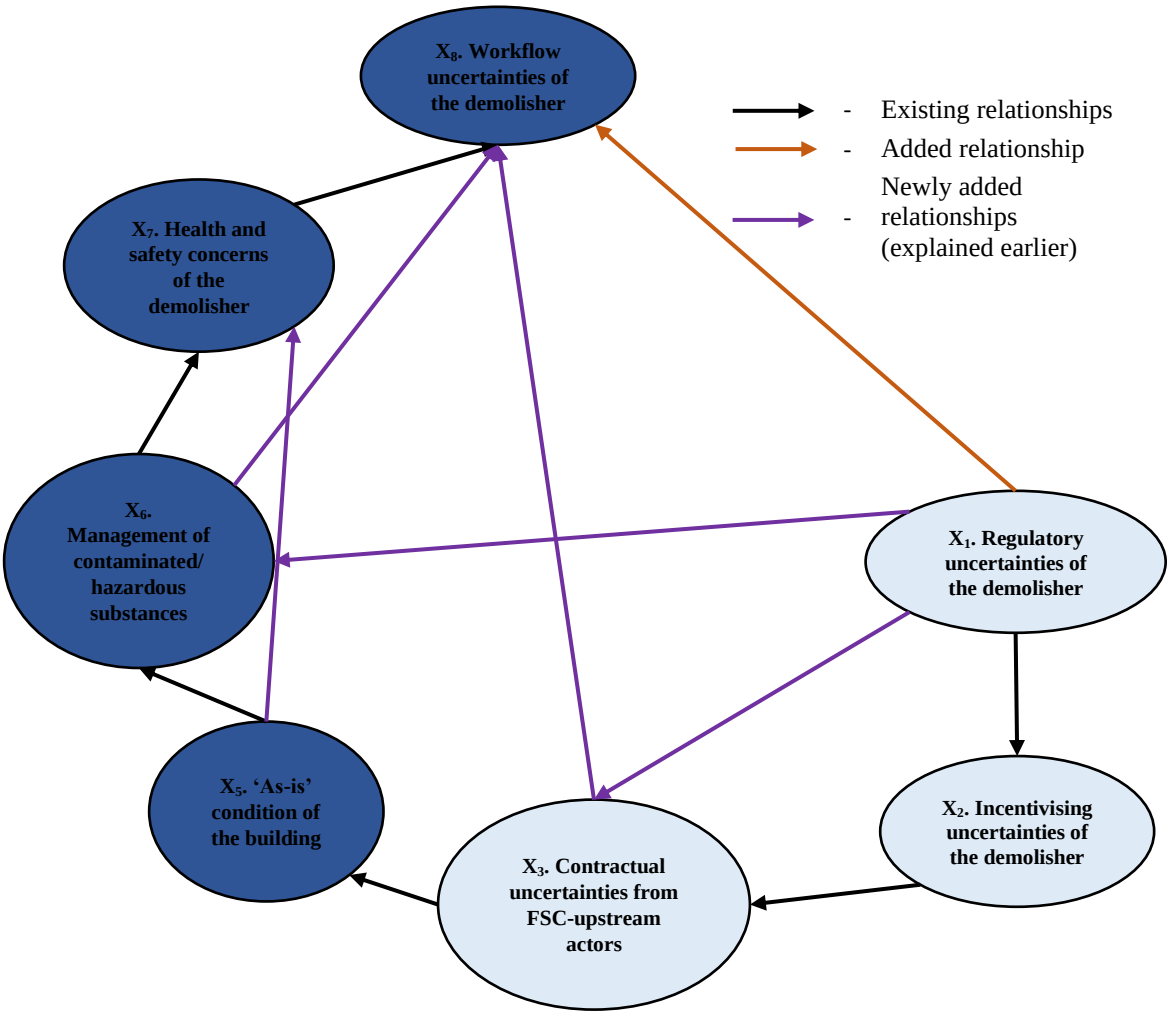


Figure 6.7. Added direct relationship between X_1 and X_8

6.3.1.8 Direct relationship between 'regulatory uncertainties of the waste processor (X_9)' and 'contractual uncertainties from FSC-downstream actors (X_{11})'

As in the case of the building dismantling and on-site processing phase, participants agreed to add a direct relationship between 'regulatory uncertainties of the waste

processor (X_9)' and 'contractual uncertainties from FSC-downstream actors (X_{11})'. Participant FGP1 mentioned that reprocessed products are mostly used in infrastructure projects in SA, for which the client is the government (i.e., the DIT). Private clients of commercial and residential projects are reluctant to use reprocessed products unless the project has a specific requirement. One reason for the minimal usage of reprocessed products is the unavailability of specifications for reprocessed products. For this reason, the FSC-downstream actors cannot specify to waste processors the quality parameters they expect from reprocessed products used in their projects. Participant FGP1 highlighted that unavailability of a regulation exclusively for waste management is the primary reason for not having specifications for reprocessed products:

> Of course, the lack of incentives, especially from the government, is a cause for the reluctance of actors to use reprocessed products in their projects. Even if the incentives are available, if there is no regulatory involvement for specifying standard quality requirements, again, there will be hesitation to use reprocessed products.

Consequently, a new relationship was added to the BBN-based conceptual model between 'regulatory uncertainties of the waste processor (X_9)' and 'contractual uncertainties of the FSC-downstream actors (X_{11})'. As shown in Figure 6.8, this is a direct relationship between these epistemic uncertainties, beyond the prevailing indirect relationship through 'incentivising uncertainties of the waste processor (X_{10})'.

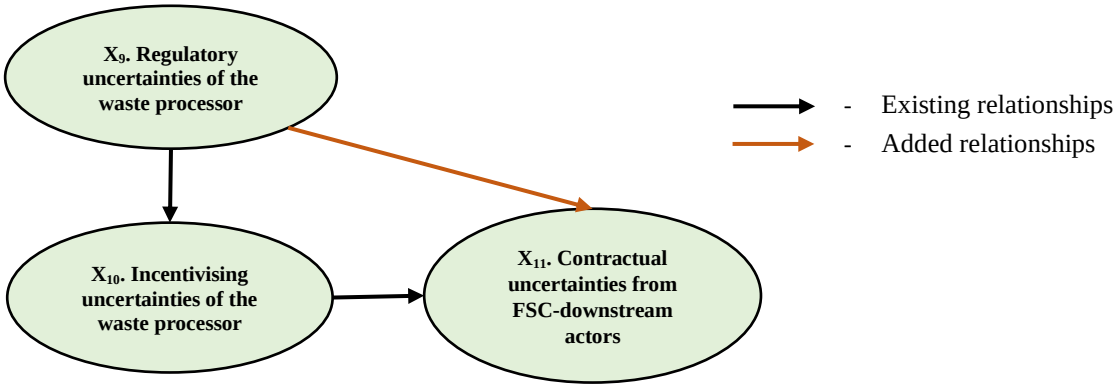


Figure 6.8. Added direct relationship between X_9 and X_{11}

6.3.1.9 Direct relationship between 'product description complexities (X_{13})' and 'human errors (X_{14})'

As shown in Figure 6.9, participants suggested adding a direct relationship between 'product description complexities (X_{13})' and 'human errors (X_{14})'. Participant FGP3 elucidated that human errors could arise when waste processors are not well versed in the requirements expected by end-users from reprocessed products.

> Understanding the customers' requirements is important because all the internal procedures are prepared to fulfil those. Based on those expectations, we alter our internal production procedures if there are changes to make and if these changes are worthy of being considered. If the information is not collected, the internal procedures go wrong, and there is a high tendency to make a lot of human errors.

Further supporting this statement, Participant FGP2 pointed out that:

> … It is very difficult to understand the end-user requirements because they have negative thoughts. Sometimes vague and complicated feedback may come. But there needs to be a consensus like one customer saying that one day, your product's not very good today is, you know, it's not a reason to change everything. So, you need to collate all the information and make a decision. There's obviously a problem if we continually get feedback about a certain aspect of our product. If not otherwise, changes to the existing process for no reason are also reasons for many human errors.

In conclusion, human errors may occur when the end-user requirements are not collected or are collected but are not accurate or applicable. Therefore, the insertion of a direct relationship between 'product description complexities (X_{13})' and 'human errors (X_{14})' is admissible.

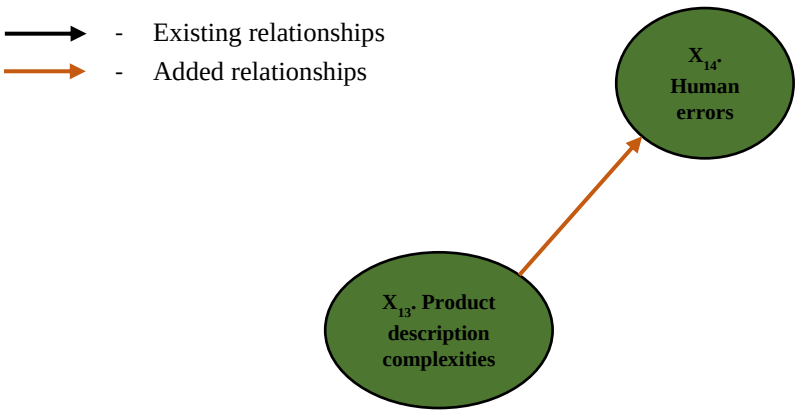


Figure 6.9. Added direct relationship between X_{13} and X_{14}

6.3.1.10 Direct relationships of 'human errors (X_{14})'–'health and safety concerns of the waste processor (X_{15})' and 'human errors (X_{14})'–'workflow uncertainties of the waste processor (X_{16})'

As shown in Figure 6.10, participants pointed out the necessity of inserting links from 'human errors (X_{14})'–'health and safety concerns of the waste processor (X_{15})' and from 'human errors (X_{14})'–'workflow uncertainties of the waste processor (X_{16})'. As in the building dismantling and on-site processing phase, explained in Subsection 6.3.1.2, participants highlighted that health and safety concerns (X_{15}) interrupt the workflow of the waste processor (X_{16}). As clarified by Participant FGP2:

> Work health and safety is our number one priority. We must ensure our workplace is free from dangers and accidents because it is mostly a human-centric job. The entire production process gets affected if there is any threat to our workers.

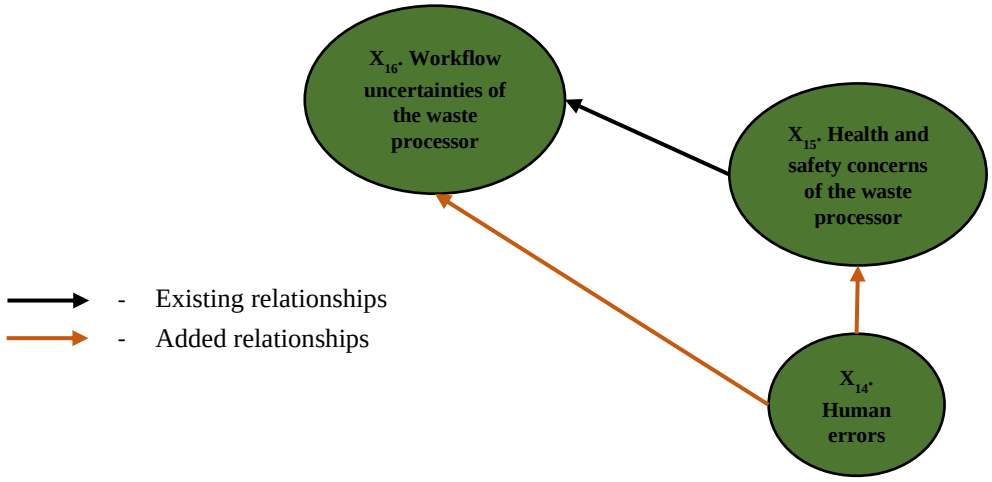


Figure 6.10. Added direct relationship between X_{14} and X_{16}

Furthermore, Participant FGP1 highlighted that most operations in a waste processing organisation are manual; thus, human errors can occur. Participant FGP1 further revealed that human errors could not only disrupt the waste processing workflow but could also exacerbate health and safety concerns of the waste processor.

> People make a lot of mistakes thinking they're doing the right [thing]. Because of this, … [a] genuine breakdowns in the workflow could happen or lead to accidents. From my experience, we had someone hurt themselves trying to lift something, and I've had a couple, and it's just a freak set of circumstances. It looked like it was light, but it was actually heavy. So, you know, manual handling injuries happen due to human errors. So even though you've got quite strict things about it, don't try and lift anything this size or this big or this heavy, some workers show how good they are by lifting and then hurt themselves.

Given these points, two new relationships were added to the BBN-based conceptual model: 'human errors (X_{14})' to 'health and safety concerns of the waste processor (X_{15})' and 'workflow uncertainties of the waste processor (X_{16})'.

6.3.1.11 Direct relationship between 'mixed waste received from demolishers (X_{12})' and 'workflow uncertainties of the waste processor (X_{16})'

Participants confirmed the indirect relationship between 'mixed waste received from demolishers (X_{12})' and 'workflow uncertainties of the waste processor (X_{16})' through 'health and safety concerns of the demolisher (X_{15})', as shown in Figure 6.11. Participant FGP2 explained this as follows:

> And especially at some sites, you know, there's a high risk of receiving mixed waste, including asbestos or other non-contaminants. That's from a PCA, [potentially contaminated activity]. There are non-PCAs too. That's where you live, where I live. So that's a non-PCA. If the waste is from a PCA, there is a risk for health and safety from silica and asbestos and things like that. When work health and safety are at risk, the workflow will obviously be disrupted.

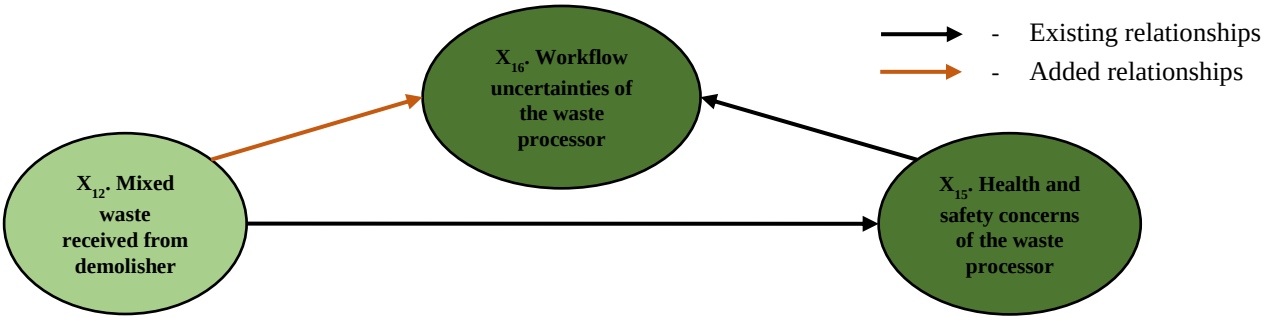


Figure 6.11. Added direct relationship between X_{12} and X_{16}

In addition to this indirect relationship, participants also pointed out a direct relationship between 'mixed waste received from demolishers (X_{12})' and 'workflow uncertainties of the waste processor (X_{16})'. Participant FGP1 revealed that:

> Sometimes, we have non-ferrous metals get into the plant. But from a quality point of view, they wouldn't get into the end-product because they'll lock up the crusher and stop the crusher from crushing the metal. So, when we cleaned out the crusher, we'd get rid of the middle. It's about to try and stop it, getting into the crusher. So, stay on time, lose production. Sometimes, there might have been unknown lead. I want to know that it might have also been making aluminium, and I might have aluminium in that product. I definitely want to know that because that oxidises in the pavement material and is under the asphalt and pumps it. So, I definitely want to know those things.

This emphasised that mixed waste from demolishers creates an uncertain workflow despite the absence of health and safety concerns. On this note, a new link was added to the conceptual model between 'mixed waste received from demolishers (X_{12})' and 'workflow uncertainties of the waste processor (X_{16})', as shown in Figure 6.11.

6.3.1.12 Direct relationship between 'regulatory uncertainties of the waste processor (X_9)' and 'health and safety concerns of the waste processer (X_{15})'

As explained in Subsections 6.3.1.8, 6.3.1.9 and 6.3.1.10, with the agreement of participants, new links were added to the BBN-based conceptual model, as indicated in purple arrows in Figure 6.12. Participants also agreed on existing links in the conceptual model, namely, 'incentivising uncertainties of the waste processor (X_{10})'–'human errors (X_{14})' and 'contractual uncertainties from FSC-downstream actors (X_{11})'–'product description complexities (X_{13})'. However, participants highlighted the need to add a direct relationship between 'regulatory uncertainties of the waste processor (X_9)' and 'health and safety concerns of the waste processor (X_{15})', even if indirect relationships existed between them. Therefore, a new link was added to the BBN-based model between 'regulatory uncertainties of the waste processor (X_9)' and 'health and safety concerns of the waste processor (X_{15})', as shown in Figure 6.12.

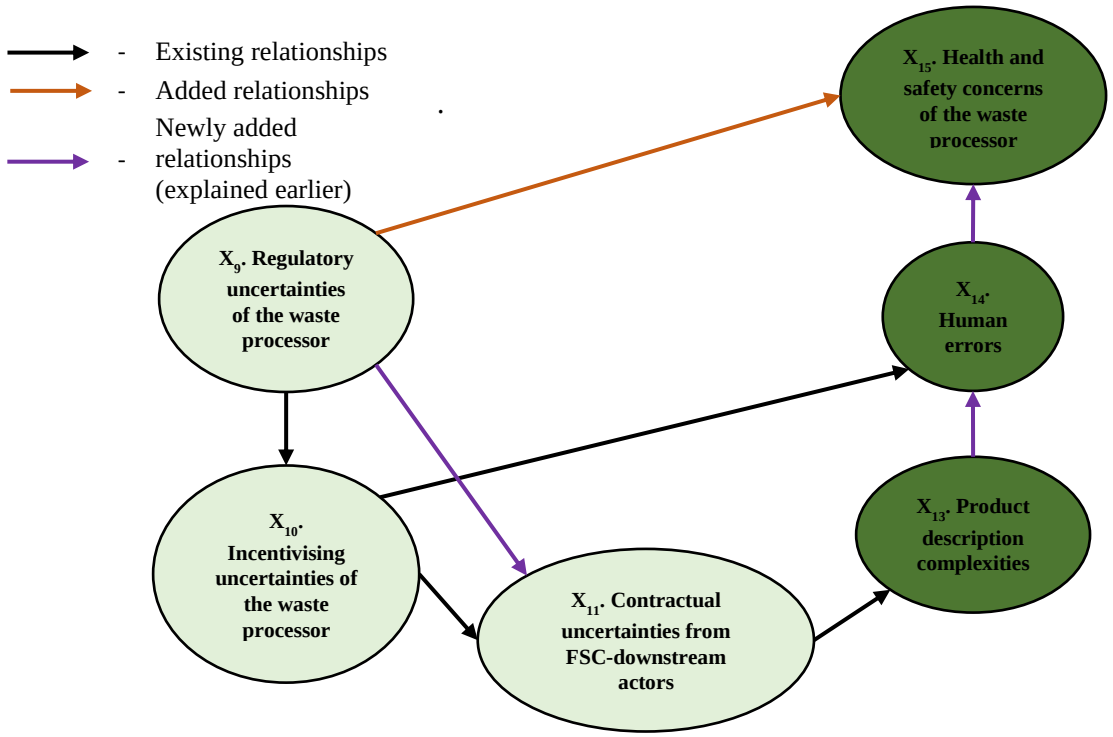


Figure 6.12. Added direct relationship between X_9 and X_{15}

6.3.1.13 Direct relationship between 'regulatory uncertainties of the waste processor (X_9)' and 'workflow uncertainties of the waste processor (X_{16})'

As explained in Subsections 6.3.1.8, 6.3.1.9, 6.3.1.10 and 6.3.1.12, focus group participants suggested adding new relationships between epistemic uncertainties, as shown by purple arrows in Figure 6.13. These newly added links formed an indirect relationship between 'regulatory uncertainties (X_9)' and 'workflow uncertainties of the waste processor (X_{16})' via different routes. Despite these indirect relationships, participants noted the need for a direct relationship between X_9 and X_{16}, as shown in Figure 6.13. Participant FGP3 explained this as follows:

> Resource recovery is such a new emerging industry; you go out and seek, and there are no regulations. Recovery is not captured in any of the trades. It's not captured in any government literature. You've got logistics, you've got waste, you've got mining, but there's no resource recovery. So, if I can do anything to legitimise that and make it a more recognised sector, I'm all for it. But at the moment, you can be a small-scale waste management transfer station. So, I think it would be good. And whether you have criteria of what you can and can't do. But I think anything that would, from our perspective and my perspective, I think it would be a good thing. I don't know what the costs would be, or which government agency would have to supervise that.

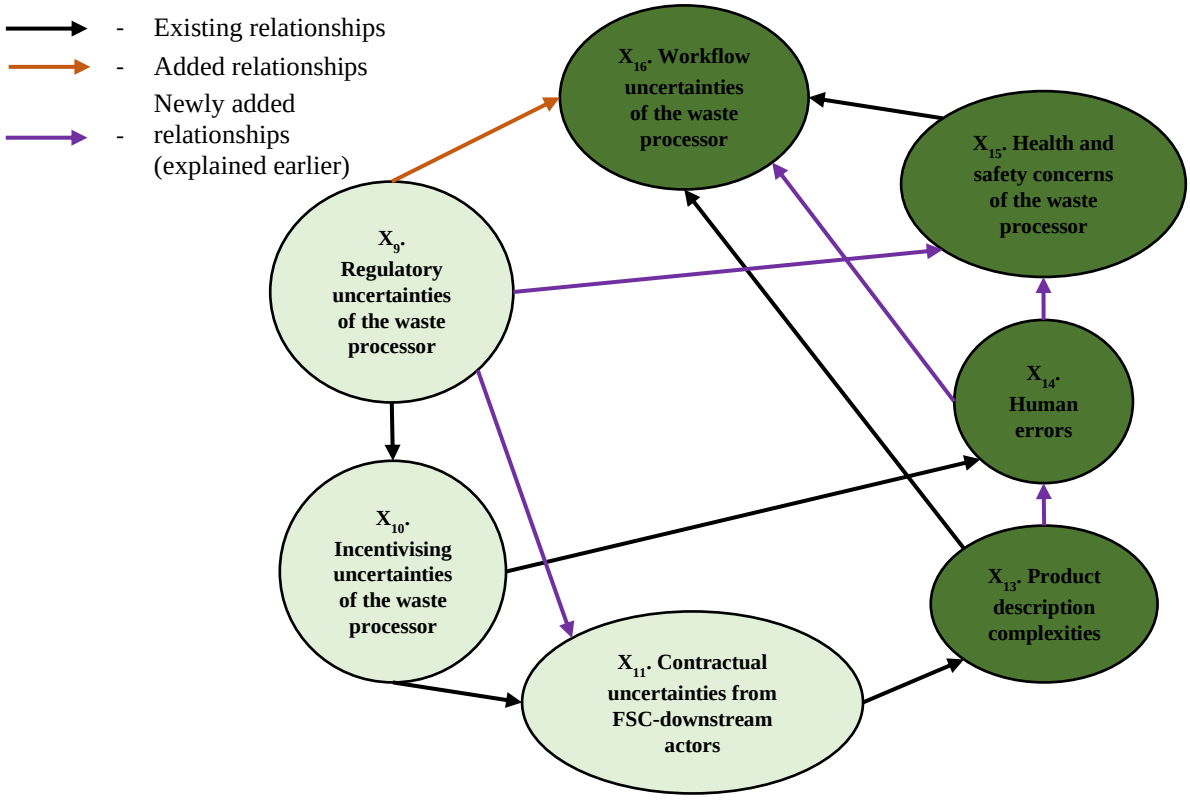


Figure 6.13. Added direct relationship between X_9 and X_{16}

Participant FGP2 emphasised that, even if large-scale waste processors have physical and financial resources, small and medium-scale waste processors cannot develop every procedure for their work. Therefore, regulatory uncertainties adversely affect the workflows of small and medium-scale waste processors more than large-scale waste processors. In line with these statements, a direct relationship was added to the model between 'regulatory uncertainties of the waste processor (X_9)' and 'workflow uncertainties of the waste processor (X_{16})', as shown in Figure 6.13.

6.3.1.14 Direct relationship between 'workflow uncertainties of the demolisher (X_8)' and 'Y. QA in RLSCs of DW'

In the existing conceptual model, an indirect relationship is found between 'workflow uncertainties of the demolisher (X_8)' and 'Y. QA in RLSCs of DW' through epistemic uncertainties, such as 'mixed waste from demolishers (X_{12})', 'health and safety concerns of the waste processor (X_{15})' and 'workflow uncertainties of the waste processor (X_{16})'. As explained in Subsection 6.3.1.11, a new link was added between 'mixed waste from demolishers (X_{12})' and 'workflow uncertainties of the waste processor (X_{16})', as suggested by participants. This new addition further strengthened the indirect relationship between X_8 and X_{16} by another route via X_{12} and X_{16}. Participant FGP5 explained this link as follows:

> When you've got a waste processing business, and you've got 40 people working for you, and you've got A$10 million worth of investment in a bank; unfortunately, you can only do so much, and then you need a quality product. So, if you end up taking mixed waste, and then do the best you can with it, and try and upgrade it, and try and clean it up and try and get it right, no good result will be produced. But the reality is that you get good quality feedstock and good quality products.

In addition to the indirect relationship, focus group participants highlighted that a direct relationship should exist between X_8 and Y. Participant FGP5 noted that the process quality of demolishers is also important for QA in RLSCs of DW. Participant FGP3 argued that, as RLSCs include demolition and waste processing as consecutive phases, the quality of the demolisher's workflow is crucial to determining the waste processor's process quality and the quality of the entire process. Therefore, sometimes, epistemic uncertainties in the workflow of demolishers are more influential than those of waste processors on QA in RLSCs of DW. Prompted by this statement, a new link was added from 'workflow uncertainties of the demolisher (W_8)' to 'Y. QA in RLSCs of DW', as shown in Figure 6.14.

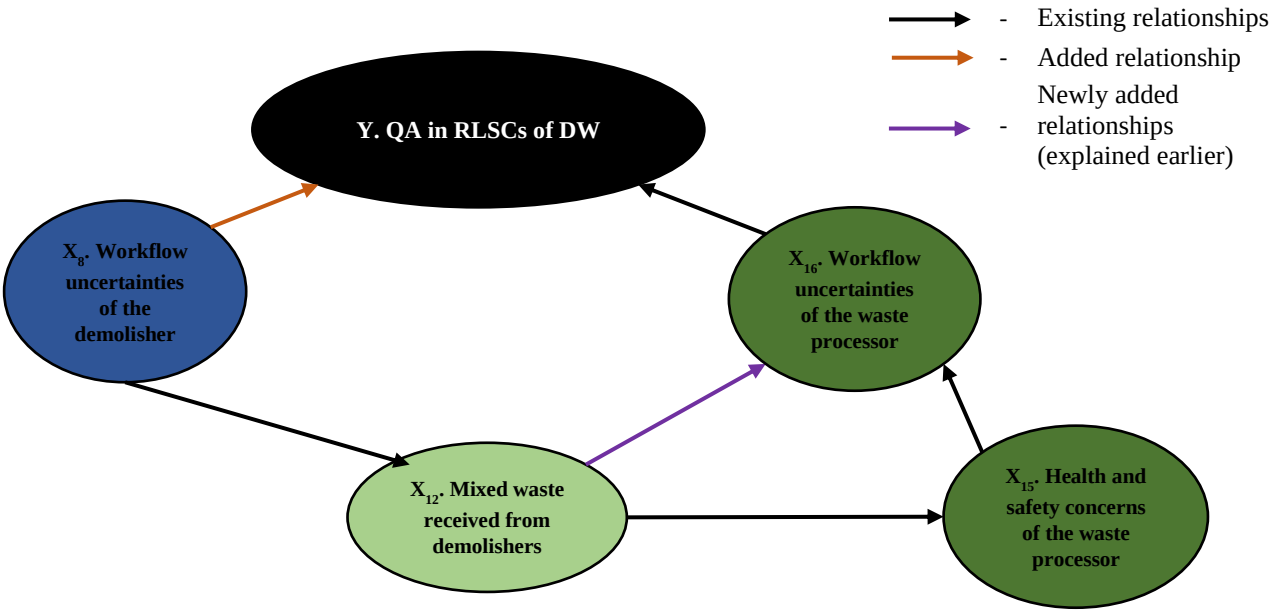


Figure 6.14. Added direct relationship between X_8 and Y

6.3.2 Deductions from the BBN-based model

As with the process through which participants added new relationships to the BBN-based conceptual information processing model (see Subsection 6.3.1), they suggested deducting the two relationships of 'human errors (X_{14})' with 'planning and goal setting (IPM_2)' and 'creation of special reports (IPM_{10})'. Participant FGP4 emphasised that no requirement is in place for IPM_2 and IPM_{10} in response to human errors due to the new relationship added between 'product description complexities (X_{13})' and 'human errors (X_{14})' (see Subsection 6.3.1.9), as shown in Figure 6.15. With this new relationship, the impact of IPM_2 on 'contractual uncertainties from FSC-downstream actors (X_{11})' is indirectly exerted on 'human errors (X_{14})' through 'product description complexities (X_{13})'. Participant FGP4 mentioned that 'planning and goal setting (IPM_2)' is a primary mechanism that could proactively respond to known and prior-experienced epistemic uncertainties. Therefore, it is more appropriate that this IPM be undertaken in response to a root cause level epistemic uncertainty, such as 'contractual uncertainties from FSC-downstream actors (X_{11})', as a preventive mechanism to avoid other epistemic uncertainties.

The BBN-based conceptual model (see Chapter 5, Figure 5.7) indicates that IPM_{10} appropriately responds to 'product description complexities (X_{13})' and 'human errors (X_{14})'. However, Participant FGP3 argued that 'creation of special reports (IPM_{10})' only avoids 'human errors (X_{14})' by avoiding 'product description complexities (X_{13})'. With

this statement, links from X_{14}–IPM_2 and from X_{14}–IPM_{10} were removed from the BBN-based conceptual model, as shown in Figure 6.15.

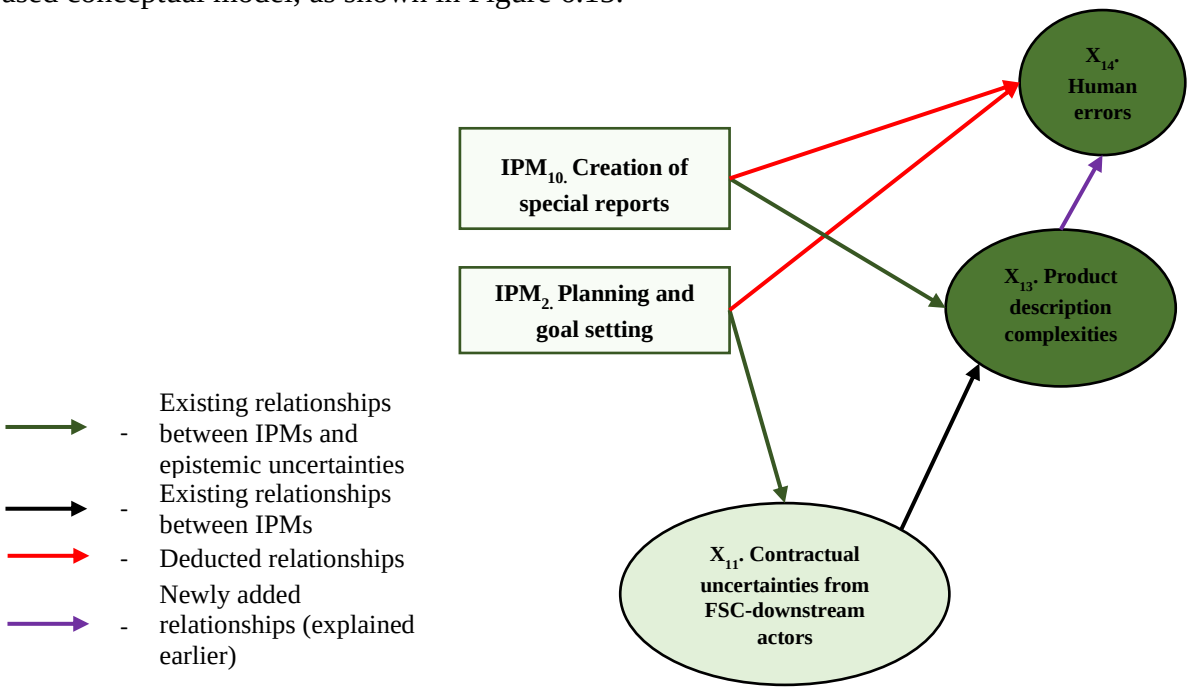


Figure 6.15. Deductions from the conceptual model

6.4 Overall Assessment of the BBN-based Information Processing Model for QA in RLSCs of DW

Figure 6.16 shows the final BBN-based conceptual information processing model for QA in RLSCs of DW developed through alterations from the summarised additions and deductions from focus group participants' suggestions.

Additions

Regulatory uncertainties of the demolisher – Contractual uncertainties from FSC-upstream actors (X_1-X_3)

Management of demolisher's sub-contractors – Workflow uncertainties of the demolisher (X_4-X_8)

'As-is' condition of the building – Health and safety concerns of the demolisher (X_5-X_7)

Management of contaminated/hazardous substances – Workflow uncertainties of the demolisher (X_6-X_8)

Regulatory uncertainties of the demolisher – Management of contaminated/ hazardous substances (X_1-X_6)

Contractual uncertainties from FSC-upstream actors – Workflow uncertainties of the demolisher (X_3-X_8)

Regulatory uncertainties of the demolisher – Workflow uncertainties of the demolisher (X_1-X_8)

Regulatory uncertainties of the waste processor – Contractual uncertainties from FSC-downstream actors (X_9-X_{11})

Product description complexities – Human errors (X_{13}-X_{14})

Human errors – Health and safety concerns of the waste processor (X_{14}-X_{15})

Human errors – Workflow uncertainties of the waste processor (X_{14}-X_{16})

Mixed waste received from demolishers – Workflow uncertainties of the waste processor (X_{12}-X_{16})

Regulatory uncertainties of the waste processor – Health and safety concerns of the waste processor (X_9-X_{15})

Regulatory uncertainties of the waste processor – Workflow uncertainties of the waste processor (X_9-X_{16})

Workflow uncertainties of the demolisher – QA in RLSCs of DW (X_8-Y)

Deductions

Human errors – Planning and goal setting (X_{14}-IPM_2)

Human errors -–Creation of special reports (X_{14}-IPM_{10})

The overall assessment of the BBN-based conceptual information processing model for QA (see Figure 6.16) is discussed in the next subsections under two headings: (i) overall assessment of the positioning of epistemic uncertainties that lead to IPNs and (ii) overall assessment of the positioning of IPMs in the model.

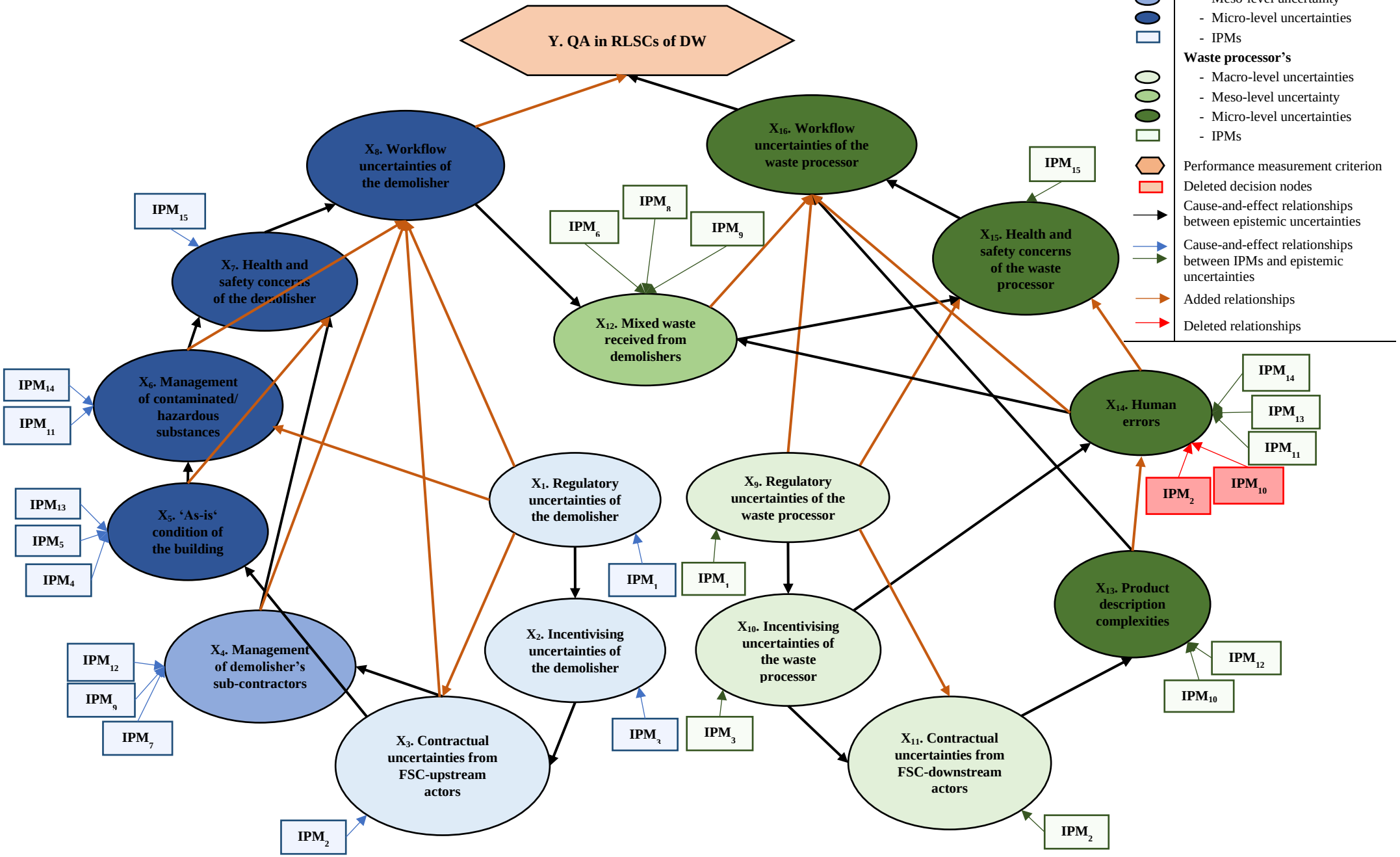


Figure 6.16. BBN-based conceptual information processing model for QA with alterations

6.4.1 Overall assessment of positioning of epistemic uncertainties in the BBN-based conceptual information processing model for QA in RLSCs of DW

In Figure 6.16, the BBN-based conceptual information processing model for QA is shown, indicating all alterations made with the agreement of focus group participants. In this model, the brown arrows represent the added relationships, while the red arrows represent the deleted ones. This model comprises two parent chance nodes: 'regulatory uncertainties of the demolisher (X_1)' and 'regulatory uncertainties of the waste processor (X_9)'. In this regard, Participant FGP4 explained the rationale for 'regulatory uncertainties' being parent nodes:

> So to speak, the problem starts with state and local government. The government does have a higher role. The care and responsibility are on their side of the line. The chain of custody has to be here (i.e., with the government). And then, in the midst of all of that, you have an EPA trying to regulate. Now they're going to write a document to make it easier, but they can be really hard; they cannot quite understand what you're trying to achieve. From the waste processors' perspective, most available standards only apply to the end-products; they don't apply to the feedstock. But if they have a product that these guys aren't going to get, they're not going to accept. Then it's not even going to come to them. It ends up going to a landfill.

According to Participant FGP4, regulatory bodies, including state and local government agencies, exist at the starting point of the chain of custody in RLSCs of DW. Due to the crucial nature of the role played by regulatory bodies, even a slight lapse in their influence on internal processes creates regulatory uncertainties. Focus group participants agreed that these regulatory uncertainties are the root causes of the remaining macro-level uncertainties.

> With all the suggested alterations, this model should be valid and acceptable. I think this arrangement is correct. When considering the QA of the reverse supply chain, the regulatory uncertainties should appear to be the base, and on top of that, these incentivising and contractual uncertainties and then the remaining internal uncertainties arise. (Participant FGP2)

Given this point, focus group participants confirmed that epistemic uncertainties are propagated through macro-level uncertainties to meso- and micro-level uncertainties.

Participants noted that 'mixed waste received from demolishers (X_{12})' is significant as it is the only epistemic uncertainty arising from the corporate relationship between the demolisher and the waste processor. Participant FGP3 emphasised that when mixed waste is not spotted at the weighbridge and is processed at the plant, the end-product

quality is difficult to assure. Therefore, Participant FGP3 highlighted that the quality of feedstock from demolition sites is important to assure the process quality of end-products from the waste processor:

> The demolition waste is mostly received as concrete waste, obviously, broken timber and things like that. But it is always important to check what's coming to the site from the demolisher, whether it's clean concrete and make sure it's clean concrete and doesn't tie into asbestos or other materials. So, with all that, I check to make sure it's not contaminated, doesn't smell, doesn't look strange and make sure we got reports.

Participants also acknowledged the direct relationships between the performance criterion of the model, that is, QA in RLSCs of DW and workflow uncertainties of the demolisher and the waste processor. Participant FGP1 stated that, as in the status quo representation of the model (see Figure 6.16), the macro-, meso- and micro-level uncertainties (i.e., excluding workflow uncertainties) interact and are propagated through to workflow uncertainties. Therefore, it is reasonable for the performance criterion (i.e., Y. QA in the RLSC of DW) to have direct relationships with workflow uncertainties of the demolisher and the waste processor.

Furthermore, focus group participants confirmed that the 16 epistemic uncertainties in the BBN-based conceptual information processing model, categorised as macro-, meso- and micro-level uncertainties, could be found in any RLSC, irrespective of the size of organisations in the supply chain. However, Participant FGP5 stressed that the degree of impact of these epistemic uncertainties on QA would differ depending on supply chains of large-scale and small and medium-scale organisations. For instance, Participant FGP5 stated that:

> It's easier for big companies to say that we're green, doing well, we're this, and we're that. So, all of that is because of a piece of government, they can get into government jobs easily, and the government is also funding them to grow. It's just you scratch my back; I'll scratch your back. I don't know, I've tried to get grants for recycling, and they don't want to give that. I don't know why it is. It's just inefficiencies of the government.

Through this example, Participant FGP5 emphasised that the effect of incentivising uncertainties, a macro-level uncertainty, differs with the size of the organisations in RLSCs of DW. Similarly, the impact of all the remaining macro-, meso- and micro-level uncertainties varies with the organisation's context in the supply chain, that is, whether it is large scale or small and medium scale. Therefore, Participant FGP5 suggested that applying the model separately to supply chains comprising large-scale

organisations and then to small-scale and medium-scale organisations would obtain interesting and contrasting findings.

6.4.2 Overall assessment of positioning of IPMs in the BBN-based conceptual information processing model for QA in RLSCs of DW

In addition to deducting a few redundant links between IPMs and epistemic uncertainties, as explained in Subsection 6.3.2, focus group participants confirmed the extant positioning of all IPMs in the model. Participant FGP2 stated that in any organisation, whether it is large scale or small and medium scale, 'rules and programs (IPM_1)' and 'planning and goal setting (IPM_2)' are established to provide a known response to epistemic uncertainties that have arisen in the past and are recurrent. With regulatory and contractual uncertainties being well understood and lasting longer, Participant FGP2 highlighted that 'rules and programs (IPM_1)' and 'planning and goal setting (IPM_2)' are appropriate IPMs in response to both types of uncertainties. From the perspective of 'rules and programs (IPM_1)', Participant FGP2 explained this as follows:

> Everyone has internally established formal rules and policies. The regulations don't endorse everything you should do or what you want. So, the internal policies are really the standards and the box-ticking, like I said there. Get a hold of what you want to try and do. And then underneath, that is where the real work happens. Policies are written with the best intentions to avoid all these uncertainties, but [a] policy on its own means absolutely nothing. It looks good and sounds good, but without anything else happening underneath, it will only be a paper.

According to Participant FGP2, even if 'rules and programs (IPM_1)' and 'planning and goal setting (IPM_2)' are undertaken in response to regulatory and contractual uncertainties, respectively, their impact also reduces the remaining macro-, meso- and micro-level uncertainties. However, this impact becomes ineffective when moving from the bottom to the top of the model with increased levels of uncertainties. In these situations, appropriate IPMs should be undertaken, as shown in the BBN-based conceptual information processing model (see Figure 6.16), in response to increased levels of IPNs.

Moreover, participants confirmed that 'business partnering (IPM_3)' is an appropriate IPM to respond to incentivising uncertainties of the demolisher and the waste processor. Participant FGP5 highlighted that demolishers and waste processors could expand to become business partners as more capital would be available for their businesses

through partnering. With this capital, organisations in the supply chain could easily sustain themselves without depending on incentivising schemes from external bodies:

> You know, we and … have a very good business partnership even if there is less formality. Because of this, more combined resources are available, including money to invest in both our businesses which help us grow. Also, each of us brings our own expertise, knowledge, skills and experience; thus, this gives us more opportunistic success than working individually. (Participant FGP5)

Participant FGP3 added that 'business partnering (IPM_3)', through responding to incentivising uncertainties, also reduces the remaining uncertainties that are directly and indirectly linked with incentivising uncertainties. However, Participant FGP3 emphasised that it was mostly large-scale organisations that undertook business partnerships, but not small and medium-scale demolishers and waste processors.

Unlike the case of macro-level uncertainties, demolishers and waste processors undertook different IPMs in response to meso-level uncertainties, except for 'forming contracts (IPM_9)'. Participant FGP1 mentioned that demolishing and waste processing organisations undertook contractual mechanisms to address meso-level uncertainties. However, Participant FGP1 stressed that using contracts to manage sub-contractors had become ineffective for some demolishers as their contracts were almost the same for every job. On the other hand, only large-scale waste processors form contracts with specific demolishers to avoid receiving mixed waste. In addition to forming contracts, demolishers and waste processors could implement a few other IPMs in response to meso-level uncertainties, as shown in Figure 6.16. Focus group participants agreed that demolishers could hold group meetings (IPM_{12}) and carry out performance evaluations (IPM_7) to manage sub-contractors, while waste processors could employ waste acceptance criteria/gate fees (IPM_8) and integrator roles (IPM_6) to avoid receiving mixed waste from demolishers at their processing plants.

All participants in the focus group discussion agreed with the positioning of IPMs around the micro-level uncertainties of both the demolisher and the waste processor. From the demolisher's perspective, Participant FGP4 stated that:

> This is correct. We conduct site visits, pre-demolition audits, collect drawings and asbestos registers to be familiar with the building that is completely unknown to us before starting the demolition. Sometimes, if it is too complicated to ascertain, my people sometimes come to me to get advice on how to proceed.

Participant FGP4 further confirmed that demolishers invest in technologies (IPM_{11}) and incorporation of expert teams (i.e., self-contained groups [IPM_{14}]) to manage contaminated/ hazardous substances (X_6). Similarly, from the waste processor's perspective, Participant FGP3 mentioned that group meetings (IPM_{12}) and the creation of special reports (IPM_{10}) are appropriate IPMs to be undertaken in response to product description complexities (X_{13}). In addition, Participant FGP3 revealed that as waste processing is highly labour intensive, human errors are a major concern for waste processors. Therefore, waste processors could undertake IPMs, such as incorporating self-contained groups (IPM_{14}), hierarchical referral (IPM_{13}) and technological investments (IPM_{11}), in response to human errors (X_{14}).

According to Figure 6.16, most IPMs appear in response to the meso- and micro-level uncertainties positioned at the middle level of the model. Notably, only one IPM appears in response to each macro-level uncertainty positioned at the root cause level of the model. Focus group participants agreed with this arrangement of the IPMs in the model. According to Participant FGP5, the 'creation of slack resources (IPM_{15})' is the only IPM that appears to be especially in response to health and safety concerns of both the demolisher (X_7) and the waste processor (X_{15}). Notably, the workflow uncertainties of the demolisher (X_8) and the waste processor (X_{16}) located at the top of the model do not have any IPMs. Participant FGP5 asserted that:

> Even after undertaking all of these mechanisms (i.e., the remaining IPMs in the model), if there is a risk to health and safety, the last resort is to increase the planning targets. For example, we temporarily cease the job in some instances until safety measures are taken if it is a risk for demolishers.

Given this point, Participant FGP5 emphasised that 'creation of slack resources (IPM_{15})' is the final course of action that the demolisher and the waste processor could undertake if all the other IPMs failed to eliminate health and safety concerns. Therefore, the absence of IPMs, especially in response to workflow uncertainties, was admissible.

In addition to epistemic uncertainties (as chance nodes) and IPMs (as decision nodes), the BBN-based conceptual information processing model (see Figure 6.16) has an objective node for the performance criterion, that is, QA in RLSCs of DW. As shown in Figure 6.16, all epistemic uncertainties and their corresponding IPMs directly or indirectly impact on this performance criterion. Participants of the focus group discussion agreed with the purpose of incorporating this objective node into the model.

Importantly, Participant FGP1 further highlighted that the degree of satisfaction with achieving QA in RLSCs varies between organisations, especially between large-scale organisations and small- and medium-scale organisations.

6.5 Concluding Remarks

This chapter discussed the empirical validation process of the BBN-based conceptual information processing model for QA in RLSCs of DW through a focus group discussion. The focus group discussion findings led to several alterations to the model. Accordingly, 15 new relationships between epistemic uncertainties were added to the model. Most of the new relationships were sourced from regulatory uncertainties of demolisher and waste processor. Furthermore, a new relationship was added between workflow uncertainties of the demolisher and QA in RLSC of DW. With this, in the updated BBN-based conceptual information processing model, the QA in RLSC of DW is impacted by both workflow uncertainties of the demolisher and waste processor. Noteworthily, none of the cause-and-effect relationships between epistemic uncertainties was removed from the model after the focus group discussion. Instead, two relationships between IPMs and epistemic uncertainties were removed from the model. Herein, participants suggested deducting two relationships that 'Human errors (X_{14})' had with 'planning and goal setting (IPM_2)' and 'creation of special reports (IPM_{10})' due to the new relationship added between product description complexities (X_{13}) and human errors (X_{14}) (see Subsection 6.3.1.9). With these alterations, the cause-and-effect relationships in the model increased to 58. As with how alterations were suggested, focus group participants validated the status quo representation of the model with appropriate justifications. None of the participants suggested eliminating epistemic uncertainties or IPMs in the original model. This refined BBN-based conceptual information processing model for QA (see Figure 6.16) was then applied in two case studies, with the findings discussed in the next chapter.

7 Application of Bayesian Belief Network (BBN)-based Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

7.1 Introduction

Chapter 6 empirically validated the BBN-based conceptual information processing model for QA in RLSCs of DW by making necessary alterations as requested by focus group discussion participants. This model presents the logical sequence of epistemic uncertainties that lead to IPNs and IPMs for QA in RLSCs of DW. After empirical validation, the model next needed to be applied in the real-world context to ensure that it was useful for the industry. Given this point, the current chapter aims to assess the applicability of the conceptual model to analyse information processing for QA in the context of RLSCs of DW; thus, it was applied in two case studies. This chapter discusses the case study findings separately through within-case and cross-case analyses, as discussed in the following sections.

7.2 Background Summary of Cases

Two case studies were employed. A focus group discussion was conducted within each case to assess the applicability of the developed BBN-based conceptual model to provide a holistic understanding of information processing for QA of the selected case. As explained in Chapter 2, Section 2.3, a typical RLSC of DW includes two organisations representing the building dismantling and on-site processing phase (i.e., demolisher) and the off-site waste processing phase (i.e., waste processor). Therefore, the unit of analysis of these case studies was the supply chain dyad comprising the demolisher and waste processor. The current study used theoretical sampling to select case studies, as explained in Chapter 3, Subsection 3.5.1.4.1.

The waste processor and demolisher in the first RLSC were large-scale organisations, while the second supply chain comprised small- and medium-scale organisations. In both cases, the organisations were based in SA. To meet the ethical requirements for anonymity, the names of the organisations and the individuals were anonymised. Consequently, the waste processors were de-identified and labelled as WP1 and WP2, while the demolishers were labelled as D1 and D2, based on the supply chain to which they were related. Table 7.1 summarises the key details regarding the two cases.

7.2.1 Case I: RLSC with large-scale demolisher (D1) and waste processor (WP1)

In Case I, the demolisher (D1) and waste processor (WP1) have been leading demolition/decommissioning and waste recovery providers for over 30 years. Notably, both these organisations were business partners in the industry. Therefore, a major part of the waste coming into WP1's MRF was from D1. As shown in Table 7.1, the annual turnover of each of these organisations was more than A$250 million, with each organisation employing more than 700 employees. Furthermore, these organisations provided their services to Tier I and II construction companies. For instance, over past decades, major construction companies in SA have employed D1 for dismantling projects of the largest industrial and commercial buildings across the state. Furthermore, WP1 worked with industry majors by providing a wide range of reprocessed products, including pavement and asphalt-type material, aggregates, concrete and sand for civil and infrastructure projects in SA. For these reasons, both D1 and WP1 in Case I were considered large-scale organisations in the waste recovery industry in SA.

Both organisations, D1 and WP1, were equipped with a wide range of plants and equipment. For instance, D1 had the most innovative excavators, specialist demolition attachments and removal equipment, and a fleet of self-delivered cranes for their dismantling jobs. Similarly, WP1's MRF was equipped with high-tech processing plants, including an industrial shredder, long object separators, magnetic separators, trommel screen, and trommel oversize and flip flop separators. Both organisations were formed by an expert team of licensed, trained and experienced employees who carried out high-tech dismantling and waste processing methodologies.

Table 7.1. Profile of case study supply chains

Case	Case I		Case II	
	Demolisher (D1)	**Waste processor (WP1)**	**Demolisher (D2)**	**Waste processor (WP2)**
Year established	1990	1991	1991	2018
Annual turnover (approximately)	More than A$250 million	More than A$250 million	Less than A$250 million	Less than A$250 million
No. of employees	More than 950	More than 700	40	28
Accreditations	✓ SAI Global Quality Management System ISO 9001:2015 ✓ SAI Global Environmental Management System ISO 14001:2015 ✓ SAI Global Occupational Health & Safety Management Systems AS/NZS 4801:2001	✓ QSCE Quality Certified System ISO 9001 ✓ QCSE Environmental Certified System ISO 14001 ✓ QSCE Safety Certified System ISO 45001	✓ QSCE Quality Certified System ISO 9001 ✓ QCSE Environmental Certified System ISO 14001 ✓ QSCE Safety Certified System ISO 45001	✓ ECAAS Quality Management System ISO 9001:2015 ✓ ECAAS Environmental Management System ISO 14001:2015 ✓ ECAAS Occupational Health & Safety Management Systems AS/NZS 4801:2001
Licences	✓ Unlimited Asbestos Removal Licence – SafeWork SA ✓ Environmental Protection Authority (EPA) – Licence	✓ Environmental Protection Authority (EPA) – Licence	✓ Class B Asbestos Removal Licence – SafeWork SA ✓ Environmental Protection Authority (EPA) – Licence	✓ Environmental Protection Authority (EPA) – Licence
Products/services	✓ Demolition and decommissioning of obsolete industrial and commercial sites ✓ Asbestos removal ✓ Total or partial demolition of buildings and structures erected by tilt-up construction ✓ Multi-level and high-rise demolition ✓ Internal demolition, refurbishment and structural modifications	✓ A wide range of recycled products, including pavement and asphalt-type materials, aggregates, concrete and sand	✓ Mechanical building demolition ✓ Asbestos removal ✓ Total or partial demolition of buildings and structures erected by tilt-up construction	✓ Recycled concrete pavement materials and aggregates
Business partnering	Both these organisations are business partners		Not relevant	Not relevant

Furthermore, these organisations followed strict QA and production procedures under their accreditations with ISO 9001 (Quality Management Systems); ISO 14001 (Environmental Management System); and AS4801 (Occupational Health and Safety Management System). As physical operations were based in SA, these organisations received licences from regulatory bodies, such as the EPA and SafeWork SA. The organisation D1 had an unlimited asbestos removal licence from SafeWork SA, while all WP1 facilities were EPA-licensed.

The application of the BBN-based model was conducted using probabilistic inferences from Case I. For this, a focus group discussion was conducted involving four experts. The profile of focus group participants is outlined in Table 7.2.

Table 7.2. Profile of focus group participants in Case I

Participant code	Designation	Years of experience	RLSC phase (organisation code)
C1P1	Contracts Manager	19	Building dismantling and on-site processing (D1)
C1P2	Project Manager	16	
C1P3	Accounts Manager	16	Off-site waste processing (WP1)
C1P4	Accounts Manager	15	

As shown in Table 7.2, two of the participants in Case I were from the demolishing organisation, while the remaining two were from the waste processing organisation. Participants had a minimum of 10 years of experience and held management positions in their respective organisations. The key findings of the epistemic uncertainty propagation of Case I are presented in Section 7.3.

7.2.2 Case II: RLSC with small and medium-scale demolisher (D2) and waste processor (WP2)

The demolisher (D2) and waste processor (WP2) in Case II were considered family-owned small- and medium-scale organisations in the waste recovery industry in SA. The organisation D2 had provided demolition and decommissioning services for over 30 years, while WP2 only recently joined the industry. The demolisher and waste processor in Case II did not have business partnering agreements as in Case I. However, D2 contributed a major part of the waste received by WP2's MRF.

The annual turnovers of organisations in Case II were less than A$250 million, and each of these organisations employed not more than 40 employees. As shown in Table 7.1,

both these organisations were rendering a range of services in their areas of expertise, however, not to as many organisations as in Case I. For instance, D2 was not engaged in dismantling multi-level, high-rise buildings, as it was more specialised in house dismantling than in commercial and industrial buildings. Therefore, D2 provided demolishing services, especially for small housing contractors in SA. Moreover, WP2 was also not engaged in producing a wide range of reprocessed products, unlike WP1 in Case I. It produced recycled concrete pavement materials and aggregates; therefore, its customer base was not as rich as Case I's D1. Both organisations in Case II used a wide range of plants and equipment but these were not technically more capable than the plants and equipment of Case I's organisations. For instance, WP2 had a small in-house processing plant with no exhaustive separators unlike WP1. Notably, the operational teams of both organisations comprised experienced, skilled and licensed employees. Similar to Case I, both organisations in Case II had developed their internal codes of practice and working procedures complying with their accreditations in ISO 9001 (Quality Management Systems); ISO 14001 (Environmental Management System); and AS4801 (Occupational Health and Safety Management System). These organisations had received licences for their minimal level of job performance, especially the demolishers. For instance, D2 had only a Class B asbestos removal licence from SafeWork SA, meaning it was only entitled to remove non-friable asbestos but not friable asbestos (i.e., Class A).

As occurred in Case I, a focus group discussion was conducted in Case II for probability elicitation. Three participants were recruited for the focus group discussion representing both Case II organisations. The focus group participant profile is given in Table 7.3. Two participants represented the waste processing organisation, while the third participant was from the demolishing organisation. Participants had more than 15 years of experience and held management designations in their respective organisations. Section 7.4 presents the epistemic uncertainty propagation's key findings for Case II.

Table 7.3. Profile of focus group participants in Case II

Participant code	Designation	Years of experience	RLSC phase (organisation code)
C2P1	Managing Director	30	Building dismantling and on-site processing (D2)
C2P2	Work Health and Safety Manager	18	Off-site waste processing (WP2)
C2P3	Managing Director	25	

7.3 Within-Case Analysis – Case Study I

As shown in Table 7.4, participants representing demolishing (D1) and waste processing (WP1) organisations in Case I confirmed they were undertaking all IPMs in the BBN-based conceptual model. Participants were later asked to consensually fill in the given conditional probability tables (CPTs) based on their supply chain's context. The results of risk propagation analysis based on the probability elicitations of these participants are presented in the next subsection.

Table 7.4. IPMs undertaken in Case I

Organisation	IPM		Whether undertaking (√) or not (X)
Demolition organisation (D1)	IPM_1	Rules and programs	√
	IPM_2	Planning and goal setting	√
	IPM_3	Business partnering	√
	IPM_4	Collection of building documents and asbestos registers	√
	IPM_5	Site visits/pre-demolition audits	√
	IPM_7	Performance evaluation of sub-contractors	√
	IPM_9	Forming contracts	√
	IPM_{11}	Investment in technologies	√
	IPM_{12}	Group meetings	√
	IPM_{13}	Hierarchical referral	√
	IPM_{14}	Incorporation of self-contained groups	√
	IPM_{15}	Creation of slack resources	√
Waste processing organisation (WP1)	IPM_1	Rules and programs	√
	IPM_2	Planning and goal setting	√
	IPM_3	Business partnering	√
	IPM_6	Creation of integrator roles	√
	IPM_8	Waste acceptance criteria/gate fees	√
	IPM_9	Forming contracts	√
	IPM_{10}	Creation of slack resources	√
	IPM_{11}	Investment in technologies	√
	IPM_{12}	Group meetings	√
	IPM_{13}	Hierarchical referral	√
	IPM_{14}	Incorporation of self-contained groups	√
	IPM_{15}	Creation of special reports	√

7.3.1 Results of epistemic uncertainties propagation: Key findings

Figure 7.1 shows the prior marginal probabilities (see Chapter 3, Subsection 3.5.2.3) of epistemic uncertainties (with no IPMs implemented) in Case I.

As shown in Figure 7.1, when no IPMs were implemented, Case I experienced a value of 0.2095 satisfaction for QA (i.e., the utility value) at prior marginal probabilities of all epistemic uncertainties. 'Mixed waste received from demolishers (X_{12})' had the highest

marginal probability of occurring (0.8233), followed by ‘workflow uncertainties of the demolisher (X_8)’ for which the probability was 0.8057. Therefore, workflow uncertainties of the demolisher had the highest marginal probability of occurring amid the two epistemic uncertainties directly linked to ‘Y. QA in RLSCs of DW’. On the other hand, incentivising uncertainties of the waste processor (X_{10}, 0.4460) and the demolisher (X_2, 0.5588) had the lowest marginal probabilities of occurring among all epistemic uncertainties.

Figure 7.1 indicates how prior marginal probabilities of epistemic uncertainties were propagated from macro-level uncertainties through meso-level to micro-level uncertainties. Compared with all macro- and micro-level uncertainties, the demolisher’s epistemic uncertainties had higher probabilities of occurrence than those of the waste processor. However, the probability of occurrence of the demolisher’s meso-level uncertainty (i.e., ‘management of demolisher’s sub-contractors (X_4)’) was lower than that of the waste processor’s meso-level uncertainty (i.e., ‘mixed waste received from demolishers (X_{12})’). It was also lower than the prior marginal probabilities of all the demolisher’s remaining uncertainties, except for incentivising uncertainties. In contrast, the meso-level uncertainty of the waste processor had the highest probability of occurrence among all epistemic uncertainties. From the demolisher’s perspective, the prior marginal probabilities of micro-level uncertainties were higher than those of macro-level uncertainties and the meso-level uncertainty. However, this trend was not apparent in the waste processor’s context. In general, macro-level uncertainties had the lowest prior marginal probabilities compared to meso- and micro-level uncertainties; however, some exceptions were found. Given this point, it was evident that the lower probabilities of macro-level uncertainties had caused higher probabilities of the occurrence of meso- and micro-level epistemic uncertainties in RLSCs of DW.

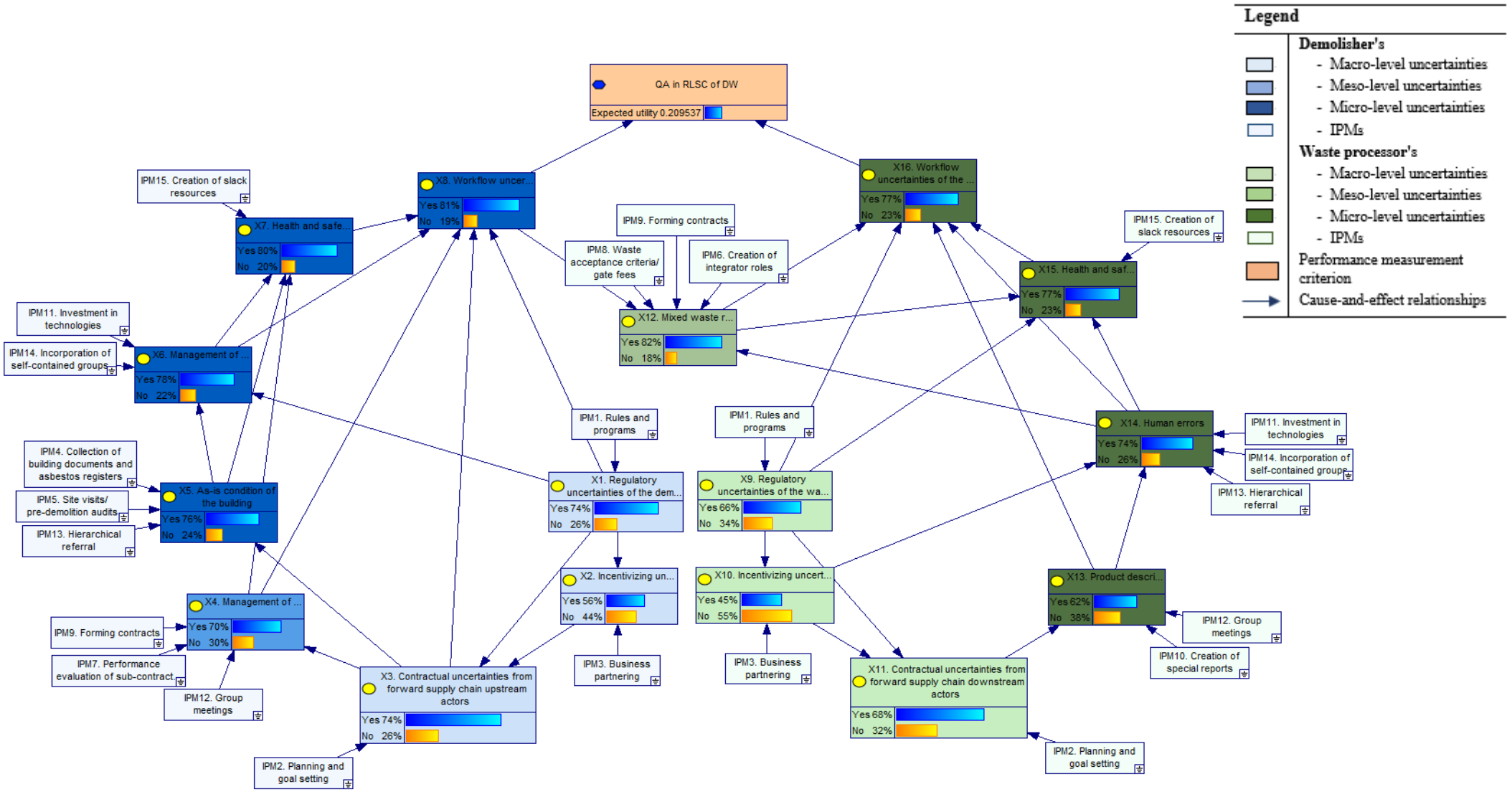


Figure 7.1. Prior marginal probabilities of the epistemic uncertainties in Case I (with no IPMs implemented)

These prior marginal probabilities only reflected the impact of epistemic uncertainty propagation on QA in the RLSC (Case I) before undertaking any IPMs. The BBN-based conceptual model further advocates a holistic understanding of information processing for QA in RLSCs, ranging from identifying the most sensitive epistemic uncertainties to how epistemic uncertainties could be overcome through employing IPMs, as discussed in the following subsections.

7.3.1.1 Sensitivity analysis

The sensitivity analysis of the model helped to gain an understanding of epistemic uncertainties in which a slight change could greatly affect QA in RLSCs of DW. The change in the utility value of QA was observed by changing the status of epistemic uncertainties (i.e., 'Yes' or 'No') in the model. The results of this analysis are shown in a tornado graph in Figure 7.2. The vertical axis of this graph represents the utility value of QA at the prior marginal probabilities of epistemic uncertainties (i.e., 0.2095). The length of a bar indicates the adjusted utility values of QA upon the change in status of epistemic uncertainties The tornado graph in Figure 7.2 thus illustrates how sensitive QA is towards each epistemic uncertainty in the RLSC of DW (Case I).

As shown in Figure 7.2, the longest bar represents 'workflow uncertainties of the demolisher (X_8)', the result of which is that the utility value of QA in Case I could change from 0.0953 (given X_8 = Yes) to 0.6832 (given X_8 = No). This indicated that QA in Case I was highly sensitive to changes in the prior marginal probability of 'workflow uncertainties of the demolisher (X_8)'. Meanwhile, 'workflow uncertainties of the waste processor (X_{16})' was the second-highest epistemic uncertainty (rated according to the sensitivity of QA in Case I). According to the BBN-based conceptual model (see Figure 7.1), workflow uncertainties of the demolisher and waste processor were directly linked to QA. Therefore, the high sensitivity of QA to workflow uncertainties was admissible. As shown in Figure 7.2, 'regulatory uncertainties of the demolisher (X_1)'; 'mixed waste received from demolishers (X_{12})'; and 'contractual uncertainties from FSC-upstream actors (X_3)' were also vital as changes in their states could significantly affect the utility value of QA in Case I. Consequently, three of the top five epistemic uncertainties to which QA was highly sensitive were the demolisher's epistemic uncertainties. Notably, two of these three were macro-level uncertainties.

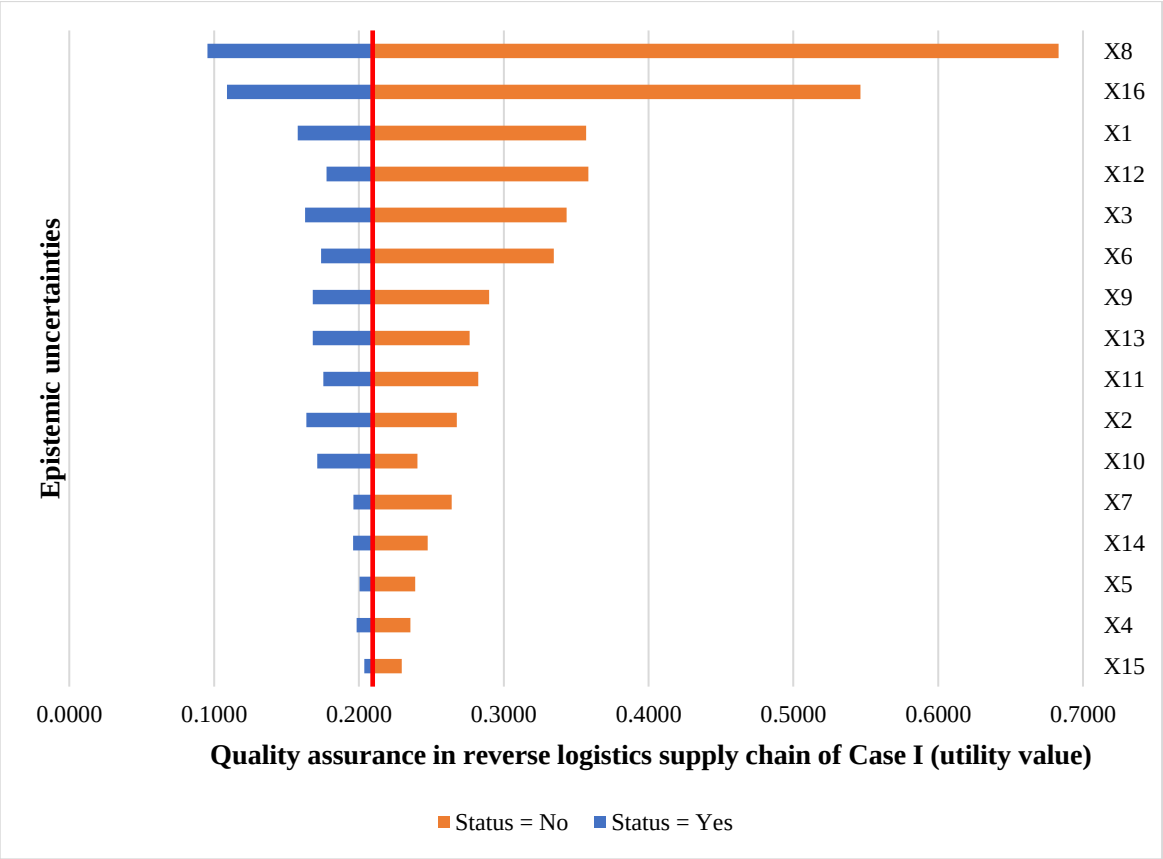


Figure 7.2. Sensitivity analysis of epistemic uncertainties in Case I

As shown in Figure 7.2, all macro-level uncertainties appear in either the top or middle levels of the tornado graph. This emphasised that QA in Case I was more sensitive to macro-level uncertainties than to the other two levels of epistemic uncertainties. The meso-level uncertainty of the waste processor (i.e., 'mixed waste received from demolishers (X_{12})') affected QA in Case I more than that of the demolisher (i.e., 'management of the demolisher's sub-contractors (X_4)'). Most micro-level uncertainties, such as 'health and safety concerns of the waste processor (X_{15})'; ''as-is' condition of the building (X_5)'; 'human errors (X_{14})'; and 'health and safety concerns of the demolisher (X_7)' appear at the bottom of the tornado graph, emphasising that QA in Case I was less sensitive to these uncertainties. It is worth highlighting that QA was least sensitive to health and safety concerns of the demolisher and waste processor. As shown in Figure 7.2, the reduction in the utility value of QA upon uncertainties having a 'Yes' status was comparatively lower than its increment for each uncertainty having a 'No' status. Therefore, if appropriate IPMs were undertaken in response to epistemic uncertainties to which QA was highly sensitive, a greater improvement in QA could be experienced in Case I.

7.3.1.2 Root cause analysis

The sensitivity analysis in Subsection 7.3.1.1 found that QA in Case I was highly sensitive to workflow uncertainties. Therefore, it is important to identify the critical path of epistemic uncertainties that augments workflow uncertainties through root cause analysis. For this identification, as discussed in Chapter 3, Subsection 3.5.2.3.3, the posterior marginal probabilities were used, which were arrived at through the concept of back-propagation, given X_8 = Yes and X_{16} = Yes. Figure 7.3 shows the critical path of epistemic uncertainties for QA in Case I, as derived from root cause analysis.

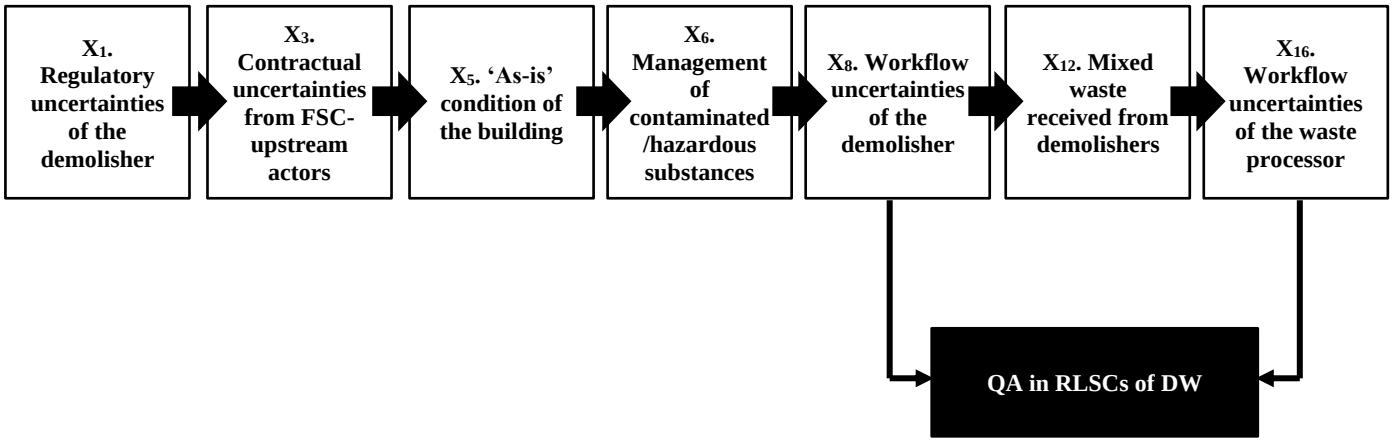


Figure 7.3. Critical path of epistemic uncertainties of Case I

When 'workflow uncertainties of the demolisher (X_8)' = Yes (i.e., 100% or 1.000), 'management of contaminated/hazardous substances (X_6)' was the most likely cause presenting with a probability of 0.8362. Therefore, 'management of contaminated/ hazardous substances (X_6)' was the significant root cause of 'workflow uncertainties of the demolisher (X_8)' in Case I. Furthermore, the most important root cause of 'management of contaminated/hazardous substances (X_6)' was ''as-is' condition of the building (X_5)', with a probability of 0.8010, when X_6 (Yes) = 100%. As the ''as-is' condition of the building (X_5)' had only one cause of epistemic uncertainty, namely, 'contractual uncertainties of the FSC-upstream actors (X_3)', it undeniably became the root cause of X_5. The BBN-based model showed that, when the occurrence of 'contractual uncertainties of the FSC-upstream actors (X_3)' had a 0.7564 probability, the ''as-is' condition of the building (X_5)' would become 100%. Similarly, when 'contractual uncertainties of the FSC-upstream actors (X_3)' = Yes (i.e., 100% or 1.000), 'regulatory uncertainties of the demolisher (X_1)' was the most likely cause to present with a probability of 0.8832. As regulatory uncertainties were the source of the

remaining epistemic uncertainties of the demolisher (see Figure 7.1), they became the root cause of this critical path.

In the same way as described above, the critical path of epistemic uncertainties was also derived for workflow uncertainties of the waste processor via root cause analysis. 'Mixed waste received from demolishers (X_{12})' was the significant root cause of 'workflow uncertainties of the waste processor (X_{16})'. For X_{16} to have a 'Yes' status, the probability of occurrence was 0.8645 for 'mixed waste received from demolishers (X_{12})'. Thus, the most likely root cause of 'mixed waste from demolishers (X_{12})' having a 'Yes' status (i.e., 100% or 1.000) was 'workflow uncertainties of the demolisher (X_8)' with a probability of 0.8332. The remaining uncertainties of the waste processor then appeared in the same sequence as found in the critical path of workflow uncertainties of the demolisher, as discussed in the above paragraph.

7.3.1.3 Analysis of IPMs

This subsection describes the effect of each and all IPMs on the prior marginal probabilities of epistemic uncertainties and the utility value of QA in Case I.

7.3.1.3.1 Analysis of change of the prior marginal probabilities of each epistemic uncertainty and the utility value of QA with implementation of <u>each</u> IPM

This subsection outlines the effectiveness of each IPM on epistemic uncertainties and QA in Case I. Table 7.5 shows how prior marginal probabilities of each epistemic uncertainty and the utility value of QA fluctuated depending on the combined and separate implementation of IPMs.

As shown in Table 7.5, the highest reduction in prior marginal probability (i.e., 85.14%) and the highest increment in the utility value of QA (i.e., 59.90%) were caused by 'rules and programs' of the demolisher (D1), specifically undertaken in response to regulatory uncertainties. As the next most effective IPM, 'rules and programs' of the waste processor (WP1) significantly reduced the prior marginal probability of regulatory uncertainties by 84.85%, thus increasing the utility value of QA by 32.52%. An interesting finding, as shown in Table 7.5, is that a vast difference existed between the changing percentages in the utility value of QA due to rules and programs and the other IPMs. Therefore, rules and programs of the demolisher and waste processor have significantly enhanced QA in Case I.

Table 7.5. Effect of <u>each</u> IPM on prior marginal probabilities of epistemic uncertainties and QA in Case I

	Epistemic uncertainties and corresponding IPMs	Prior marginal probabilities (X_y = Yes)			QA (utility value)		
		Without IPM(s)	With IPM(s)	Difference	Without IPM(s)	With IPM(s)	Difference
Demolition organisation (D1)	**X_1. Regulatory uncertainties of the demolisher**						
	Rules and programs	0.7400	0.1100	-85.14%	0.2095	0.3350	59.90%
	X_2. Incentivising uncertainties of the demolisher						
	Business partnering	0.5588	0.4966	-11.13%	0.2095	0.2102	0.32%
	X_3. Contractual uncertainties from FSC-upstream actors						
	Planning and goal setting	0.7413	0.4180	-43.62%	0.2095	0.2456	17.20%
	X_4. Management of demolisher's sub-contractors						
	Forming contracts	0.7019	0.4941	-29.60%	0.2095	0.2149	2.54%
	Performance evaluation of sub-contractors	0.7019	0.5645	-19.58%	0.2095	0.2130	1.67%
	Group meetings	0.7019	0.6322	-9.92%	0.2095	0.2113	0.83%
	All information processing capacities (IPCs)	0.7019	0.1819	-74.09%	0.2095	0.2228	6.33%
	X_5. 'As-is' condition of the building						
	Collection of building documents/asbestos registers	0.7645	0.5222	-31.69%	0.2095	0.2163	3.23%
	Site visits/pre-demolition audits	0.7645	0.5445	-28.78%	0.2095	0.2156	2.89%
	Hierarchical referral	0.7645	0.7319	-4.26%	0.2095	0.2104	0.41%
	All IPCs	0.7645	0.1690	-77.90%	0.2095	0.2257	7.71%
	X_6. Management of contaminated/ hazardous substances						
	Investment in technologies	0.7775	0.7728	-0.61%	0.2095	0.2108	0.62%
	Incorporation of self-contained groups	0.7775	0.6392	-17.78%	0.2095	0.2280	8.83%
	All IPCs	0.7775	0.5108	-34.31%	0.2095	0.2442	16.56%
	X_7. Health and safety concerns of the demolisher						
	Creation of slack resources	0.8030	0.5729	-28.65%	0.2095	0.2193	4.68%
Waste processing organisation (WP1)	**X_9. Regulatory uncertainties of the waste processor**						
	Rules and programs	0.6600	0.1000	-84.85%	0.2095	0.2777	32.52%
	X_{10}. Incentivising uncertainties of the waste processor						
	Business partnering	0.4460	0.4164	-6.64%	0.2095	0.2097	0.06%
	X_{11}. Contractual uncertainties from FSC-downstream actors						
	Planning and goal setting	0.6815	0.3878	-43.09%	0.2095	0.2215	5.70%
	X_{12}. Mixed waste received from demolishers						
	Waste acceptance criteria	0.8234	0.5219	-36.62%	0.2095	0.2368	13.00%
	Forming contracts	0.8234	0.6498	-21.08%	0.2095	0.2251	7.41%
	Creation of integrator roles	0.8234	0.6792	-17.51%	0.2095	0.2224	6.14%
	All IPCs	0.8234	0.2109	-74.38%	0.2095	0.2652	26.55%
	X_{13}. Product description complexities						
	Creation of special reports	0.6180	0.3331	-46.10%	0.2095	0.2310	10.24%

Epistemic uncertainties and corresponding IPMs	Prior marginal probabilities (X_y = Yes)			QA (utility value)		
	Without IPM(s)	With IPM(s)	Difference	Without IPM(s)	With IPM(s)	Difference
Group meetings	0.6180	0.5471	-11.47%	0.2095	0.2149	2.55%
All IPCs	0.6180	0.2045	-66.91%	0.2095	0.2407	14.86%
X_{14}. Human errors						
Investment in technologies	0.7357	0.6998	-4.87%	0.2095	0.2109	0.63%
Hierarchical referral	0.7357	0.7135	-3.01%	0.2095	0.2103	0.38%
Incorporation of self-contained groups	0.7357	0.6370	-13.42%	0.2095	0.2130	1.67%
All IPCs	0.7357	0.4418	-39.95%	0.2095	0.2196	4.82%
X_{15}. Health and safety concerns of the waste processor						
Creation of slack resources	0.7748	0.6565	-15.26%	0.2095	0.2121	1.22%

Even if reductions in the prior marginal probabilities of regulatory uncertainties due to rules and programs of both the demolisher and waste processor were nearly the same, the increase in the utility value of QA was comparatively low due to rules and programs of the waste processor. This emphasised that, even if the waste processor had developed informative rules and programs in response to regulatory uncertainties, the impact on increasing QA was comparatively lower than that of the demolisher. This finding was also admissible as per the sensitivity analysis findings which elucidated that QA in Case I was more sensitive to the demolisher's regulatory uncertainties than to those of the waste processor.

After rules and programs, the next largest increase in the utility value of QA was caused by 'planning and goal setting (IPM_2)' of the demolisher (i.e., 17.20%), followed by 'waste acceptance criteria/gate fees (IPM_8)' of the waste processor (i.e., 13.00%). These IPMs reduced the prior marginal probabilities of the epistemic uncertainties to which they were linked, namely, 'contractual uncertainties from FSC-upstream actors (X_3)' and 'mixed waste from demolishers (X_{12})' by 43.62% and 36.62%, respectively. However, IPMs of the waste processor reduced the prior marginal probabilities of corresponding epistemic uncertainties by a greater percentage than 'waste acceptance criteria/gate fees (IPM_8)'. For instance, 'creation of special reports (IPM_{10})' and 'planning and goal setting (IPM_2)' decreased the prior marginal probabilities of 'contractual uncertainties from FSC-downstream actors (X_{11})' and 'product description complexities (X_{13})' by 46.10% and 43.09%, respectively. However, increments in the utility value of QA due to these IPMs were less than the increment due to waste acceptance criteria. As found in the sensitivity analysis in Subsection 7.3.1.1, QA in

Case I was more highly sensitive to 'mixed waste received from demolishers (X_{12})' than to 'contractual uncertainties from FSC-downstream actors (X_{11})' and 'product description complexities (X_{13})'; thus, this finding was admissible. From the demolisher's perspective, all other IPMs, besides 'rules and programs (IPM_1)' and 'planning and goal setting (IPM_2)', caused a less than 10% increase in the utility value of QA. On the other hand, from the waste processor's perspective, all the IPMs except 'rules and programs (IPM_1)'; 'waste acceptance criteria/gate fees (IPM_8)'; and 'creation of special reports (IPM_{10})' caused a less than 10% increase in the utility value of QA. However, as shown in Table 7.5, increments in the utility value of QA due to IPMs of the demolisher were higher than increments created by IPMs of the waste processor. As shown in Table 7.5, the lowest increment in the utility value of QA was caused by business partnering, specifically undertaken by the demolisher and waste processor, in response to their incentivising uncertainties (X_2 and X_{10}). The demolisher and waste processor could increase the utility value of QA by less than 0.40% by undertaking business partnering as an IPM. However, business partnering reduced the prior marginal probabilities of incentivising uncertainties of the demolisher (X_2) and waste processor (X_{10}) by 11.13% and 6.64%, respectively. A few other IPMs of both the demolisher (e.g., 'investment in technologies [IPM_{11}]'; 'group meetings [IPM_{12}]'; 'hierarchical referral [IPM_{13}]') and the waste processor (e.g., 'hierarchical referral [IPM_{13}]', 'investment in technologies [IPM_{11}]') reduced the prior marginal probabilities of their corresponding epistemic uncertainties by lower percentages and succeeded in increasing the utility value of QA by slightly more than business partnering. This provided evidence that even though business partnering responded well to incentivising uncertainties, it did not succeed in increasing the utility value of QA by a considerable amount. As QA is moderately sensitive to incentivising uncertainties (as discussed in Subsection 7.3.1.1), a lower increment in the utility value of QA due to business partnering was admissible.

When considering IPMs individually, most had reduced prior marginal probabilities of their corresponding epistemic uncertainties and increased the utility value of QA at lower percentages. However, when implemented in combination (if more than one IPM per epistemic uncertainty was present), a higher percentage of reduction in prior marginal probabilities and a higher increment in the utility value of QA could be observed, as per Table 7.5. For instance, 'investment in technologies (IPM_{11})' had

reduced only 0.61% of the prior marginal probability of 'management of contaminated/hazardous substances (X_6)' and thereby increased the utility value of QA by 0.62%. 'Incorporation of self-contained groups (IPM_{14})' reduced 17.78% of the prior marginal probability of 'management of contaminated/hazardous substances (X_6)', thus increasing the utility value of QA by only 8.83%. When both these IPMs were implemented, the prior marginal probability of 'management of contaminated/hazardous substances (X_6)' was reduced by 34.31% while increasing the utility value of QA by 16.56%. Similarly, as shown in Table 7.5, many instances occurred in which IPMs successfully responded to epistemic uncertainties and then increased QA when implemented in combination rather than being separately implemented. In one interesting finding, the study found that most IPMs that were less rich and more impersonal (e.g., rules and programs, planning and goal setting) were effective when implemented separately. In contrast, most IPMs that were richer and more personal (e.g., incorporation of self-contained groups, investment in technologies) were successful if implemented in combination but not when separately implemented. However, exceptions (e.g., business partnering) could occur.

7.3.1.3.2 Analysis of change of the prior marginal probabilities of each epistemic uncertainty and the utility value of QA with implementation of all IPMs

As per the structure of the BBN-based conceptual model (see Figure 7.1), IPMs have been positioned at the most appropriate epistemic uncertainties, that is, those where they could exert a significant influence. Due to cause-and-effect relationships, each IPM's impact reduced the prior marginal probabilities of its connected epistemic uncertainty, as well as other uncertainties, directly and indirectly, as they related to its connected epistemic uncertainty. Therefore, the impact of each IPM was propagated along with epistemic uncertainties and exerted a compounding effect on increasing the utility value of QA in Case I. Given this point, Table 7.6 shows how the implementation of all IPMs impacted on each epistemic uncertainty (i.e., prior marginal probabilities) and the utility value of QA in the case study. It is important to restate that both the demolisher and waste processor in Case I were undertaking all the IPMs included in the BBN-based conceptual model (as described in Section 7.3).

Table 7.6. Effect of all IPMs on prior marginal probabilities of epistemic uncertainties and QA in Case I

		Epistemic uncertainty	Status	Without IPM (prior marginal probability)	With all IPMs that were currently implemented (prior marginal probability)	Difference (%)
Demolition organisation (D1)	X_1	Regulatory uncertainties of the demolisher	Yes	0.7400	0.1100	-85.14%
	X_2	Incentivising uncertainties of the demolisher	Yes	0.5588	0.1249	-77.65%
	X_3	Contractual uncertainties from FSC-upstream actors	Yes	0.7413	0.1308	-82.35%
	X_4	Management of demolisher's sub-contractors	Yes	0.7019	0.1392	-80.17%
	X_5	'As-is' condition of the building	Yes	0.7645	0.0957	-87.48%
	X_6	Management of contaminated/hazardous substances	Yes	0.7775	0.1782	-77.08%
	X_7	Health and safety concerns of the demolisher	Yes	0.8030	0.3835	-52.25%
	X_8	Workflow uncertainties of the demolisher	Yes	0.8057	0.3954	-50.93%
Waste processing organisation (WP1)	X_9	Regulatory uncertainties of the waste processor	Yes	0.6600	0.1000	-84.85%
	X_{10}	Incentivising uncertainties of the waste processor	Yes	0.4460	0.1140	-74.44%
	X_{11}	Contractual uncertainties from FSC-downstream actors	Yes	0.6815	0.1625	-76.15%
	X_{12}	Mixed waste received from demolishers	Yes	0.8234	0.1286	-84.38%
	X_{13}	Product description complexities	Yes	0.6180	0.1630	-73.62%
	X_{14}	Human errors	Yes	0.7357	0.2227	-69.72%
	X_{15}	Health and safety concerns of the waste processor	Yes	0.7748	0.3156	-59.26%
	X_{16}	Workflow uncertainties of the waste processor	Yes	0.7698	0.3019	-60.78%
Expected utility value of QA in RLSCs of DW				**0.2095**	**0.6396**	

As shown in Table 7.6, the utility value of QA in Case I increased from 0.2095 to 0.6396 by implementing all IPMs. As the prior marginal probabilities of all epistemic uncertainties were reduced by more than 50% after implementing all the IPMs, such a significant increase in the utility value of QA was admissible. The ''as-is' condition of the building (X_5)' was the epistemic uncertainty with the highest reduction of prior marginal probability (87.48%) (i.e., from 0.7645 to 0.0957). This indicated that all the IPMs were most effective in reducing the uncertainties related to the ''as-is' condition of the building (X_5)'. The next highest were regulatory uncertainties of the demolisher and the waste processor which received massive reductions in prior marginal probabilities after implementing all the IPMs. Notably, 'mixed waste from demolishers (X_{12})' with the highest prior marginal probability before implementing IPMs, reduced its prior marginal probability by 84.38% after implementing all the IPMs.

It is apparent from Table 7.6 that, after implementing all the IPMs, the reduction in prior marginal probabilities of macro- and meso-level uncertainties of both demolisher and waste processor was comparatively higher than for most micro-level uncertainties. Notably, the prior marginal probabilities of micro-level uncertainties of both demolisher and waste processor were reduced within a range of 50%–78%, except for ‘‘as-is’ condition of the building (X_5)’. Among all IPMs, the lowest reduction was with ‘workflow uncertainties of the demolisher (X_8)’ (50.93%). The waste processor’s workflow uncertainties (X_{16}) also had a considerably lower reduction in percentage (60.78%) compared to the other micro-level uncertainties. It is worth highlighting that, due to the influence of IPMs attached to the other epistemic uncertainties, a more than 50% reduction in prior marginal probabilities could be found in workflow uncertainties of both the demolisher and waste processor, even without any IPM attached to them. Notably, the health and safety concerns of both the demolisher (52.26%) and waste processor (59.25%) also had considerably lower percentage reductions in prior marginal probabilities compared to the other micro-level uncertainties. These epistemic uncertainties with lower reductions had higher marginal probabilities before and after implementing IPMs. As shown in the BBN-based conceptual model, in Figure 7.1, all epistemic uncertainties with the lowest reductions (i.e., workflow uncertainties and health and safety concerns) were positioned at the top level of the model. Therefore, these epistemic uncertainties were influenced by all the remaining epistemic uncertainties of the model. On that note, higher marginal probabilities of these epistemic uncertainties before and after implementing IPMs were admissible.

In conclusion, internal stakeholders in Case I were able to reduce the prior marginal probability of the occurrence of their epistemic uncertainties, each with a percentage of more than 50%, through undertaking all the IPMs. As a result, the utility value of QA was significantly augmented. The prior marginal probabilities of macro- and meso-level uncertainties were reduced by a considerably higher percentage than those of micro-level uncertainties, except for ‘‘as-is’ condition of the building (X_5)’. As QA was highly sensitive to macro-level uncertainties (see Subsection 7.3.1.1) which were positioned as root causes in the model, higher reductions in their prior marginal probabilities were a reason for enhancing QA in Case I. On the other hand, lower reductions in prior marginal probabilities of micro-level uncertainties were also acceptable as their position at the top of the model was by influencing all remaining epistemic uncertainties. These

findings established the importance of undertaking appropriate IPMs in response to root causes which, in turn, would be the reason for a considerable reduction of prior marginal probabilities of epistemic uncertainties at the top of the model while augmenting QA significantly.

7.3.1.4 Scenario analysis

Scenario analysis (see Chapter 3, Subsection 3.5.2.3.3) observes the combined effect on a particular variable(s) (i.e., observed variables) due to changes in the status of several epistemic uncertainties under different classifications (i.e., focused variables). The BBN-based conceptual model (see Figure 7.1) consisted of three macro-level, two meso-level and four micro-level epistemic uncertainties of each of the demolisher and the waste processor. This subsection analyses the effect of macro-, meso- and micro-level uncertainties on QA in RLSCs of DW. Firstly, the observed variables and focused variables were decided. The observed variables were the macro-, meso- and micro-level uncertainties (except workflow uncertainties). Workflow uncertainties of the demolisher and waste processor and QA were considered the focused variables of these scenarios. The reason for considering workflow uncertainties as a focused variable was that they underwent the systematic impact of all other epistemic uncertainties due to their position in the model (see Figure 7.1.). Next, depending on the different scenarios (i.e., Scenario A – status (Yes); Scenario B – status (No); and Scenario C – after implementing current IPMs) for each observed variable, the percentages of difference found in the posterior marginal probabilities/utility value of the focused variables were determined. The results of the analysis are discussed in the following subsections.

7.3.1.4.1 Analysis of the effect of macro-level uncertainties of each of the demolisher and waste processor on QA in RLSCs of DW

Table 7.7 outlines the effect of macro-level uncertainties of each of the demolisher and waste processor (observed variables) on workflow uncertainties and the utility value of QA (focused variables). In the worst-case Scenario A, that is, when all the macro-level uncertainties of the demolisher had a ‘Yes’ status, the prior marginal probability of ‘workflow uncertainties of the demolisher (X_8)’ increased by 13.86%. It was also found that when the demolisher’s macro-level uncertainties had a ‘Yes’ status, the prior marginal probability of the waste processor’s workflow uncertainties (X_{16}) increased by 0.45%. On the other hand, when all the macro-level uncertainties of the waste processor were present (status = Yes), the prior marginal probabilities of their workflow

uncertainties increased by 14.09%. However, as was also evident from the BBN-based model (see Figure 7.1), the waste processor's macro-level uncertainties had no impact on the workflow uncertainties of the demolisher. In this worst-case Scenario A, the presence of macro-level uncertainties of the demolisher caused a reduction in the utility value of QA by 31.34%, which was more than the reduction due to macro-level uncertainties of the waste processor (21.85%).

In the best-case Scenario B, when the demolisher's macro-level uncertainties had a 'No' status, the prior marginal probability of the demolisher's workflow uncertainties reduced by 36.46%. Compared to this, the prior marginal probability of the waste processor's workflow uncertainties reduced by 27.67% when none of the waste processor's macro-level uncertainties were present. However, it is worth noting that, from the perspectives of both the demolisher and waste processor, the reduction in the prior marginal probability of workflow uncertainties in the best-case scenario was more than the increment in the worst-case scenario. Similar to Scenario A, in Scenario B, when no demolisher's macro-level uncertainties (status = No) were present, the prior marginal probability of the waste processor's workflow uncertainties (X_{16}) reduced by 1.19%. However, this level of reduction was not found in the demolisher's workflow uncertainties (X_8) due to the absence of the waste processor's macro-level uncertainties. At the same time, the utility value of QA increased by 82.41% and 42.90% due to the absence of macro-level uncertainties of the demolisher and waste processor, respectively.

In Scenario C, the prior marginal probability of the demolisher's workflow uncertainties in Case I reduced by 31.07%, with the implementation of all the IPMs allied to their macro-level uncertainties (i.e., rules and programs, business partnering, planning and goal setting). In contrast, with the employment of IPMs corresponding to the waste processor's macro-level uncertainties, the prior marginal probability of the waste processor's workflow uncertainties reduced by 22.70%. Due to the implementation of IPMs in response to macro-level uncertainties by both the demolisher and waste processor, the utility value of QA increased by 70.24% and 35.20%, respectively. This emphasised that, of the 82.41% and 42.90% increments in the utility value of QA that could happen in the best-case scenario, 70.24% and 35.20% had already been accomplished by IPMs currently undertaken by the demolisher and waste processor, respectively, in Case I.

Table 7.7. Analysis of the effect of macro-level uncertainties of each of the demolisher and waste processor on QA in Case I

Observed variables	Focused variables	Prior marginal probability/ utility value	Without IPMs				With IPMs	
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C – With IPMs that were currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Macro-level uncertainties								
- Demolisher's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8057	0.9174	13.86%	0.5120	-36.46%	0.5554	-31.07%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.7698	0.7732	0.45%	0.7606	-1.19%	0.7620	-1.01%
	QA in RLSCs of DW	0.2095	0.1439	-31.34%	0.3822	82.41%	0.3567	70.24%
- Waste processor's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8057	0.8057	0.00%	0.8057	0.00%	0.8057	0.00%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.7698	0.8782	14.09%	0.5568	-27.67%	0.5950	-22.70%
	QA in RLSCs of DW	0.2095	0.1638	-21.85%	0.2994	42.90%	0.2833	35.20%

In conclusion, due to the macro-level uncertainties (of each of the demolisher and waste processor), the prior marginal probability of workflow uncertainties of the waste processor increased more than that of the demolisher. On the other hand, when macro-level uncertainties were absent, the reduction in the prior marginal probability of workflow uncertainties was more for those of the demolisher than for those of the waste processor. In Case I, after implementing the IPMs in response to macro-level uncertainties, the reduction in the prior marginal probability of workflow uncertainties of the demolisher was more than that of the waste processor. Furthermore, the utility value of QA was more significantly augmented with the absence of macro-level uncertainties of the demolisher than with those of the waste processor. It was found that after implementing all the IPMs, the percentage of increment in the utility value of QA due to the reduction of the demolisher's macro-level uncertainties was nearly double the increment that occurred due to the reduction of the waste processor's macro-level uncertainties. From this, it could be concluded that addressing the demolisher's macro-level uncertainties was more significant for enhancing QA in the RLSC in Case I than addressing those of the waste processor.

7.3.1.4.2 Analysis of the effect of meso-level uncertainties of each of the demolisher and waste processor on QA in RLSCs of DW

Table 7.8 outlines the effect of meso-level uncertainties (observed variables) on the workflow uncertainties of each of the demolisher and waste processor and on QA in Case I (focused variables). As shown in Table 7.8, in the worst-case Scenario A, that is, when the meso-level uncertainties of each of the demolisher and waste processor had a 'Yes' status, the prior marginal probabilities of their corresponding workflow uncertainties increased by 2.34% and 5.00%, respectively. On the other hand, in the best-case Scenario B, when the meso-level uncertainties of each of the demolisher and waste processor had a 'No' status, the prior marginal probabilities of their corresponding workflow uncertainties reduced by 5.50% and 23.29%, respectively. Furthermore, in Scenario C, after implementing all current IPMs of each of the demolisher and waste processor, the prior marginal probabilities of their workflow uncertainties decreased by 2.80% and 17.14%, respectively. Therefore, the effect of the waste processor's meso-level uncertainty on its workflow uncertainties was more significant than the effect of the demolisher's meso-level uncertainty on its workflow uncertainties.

When referring to Scenarios A, B and C, the meso-level uncertainty of the demolisher slightly impacted on the waste processor's workflow uncertainties. In contrast, due to the waste processor's meso-level uncertainty, the demolisher's workflow uncertainties fluctuated in Scenarios A and B but not in Scenario C. According to the BBN-based conceptual model (see Figure 7.1), 'mixed waste received from demolishers (X_{12})' did not affect but was being affected by the demolisher's workflow uncertainties. Therefore, as in Scenario C, after implementing all current IPMs in response to X_{12}, nothing had changed in the prior marginal probability of the demolisher's workflow uncertainties which was understandable. However, in Scenarios A and B, the changes in prior marginal probability (i.e., % of changes) of the demolisher's workflow uncertainties indicated how much of its prior marginal probability should be changed to cause 'mixed waste received from demolishers (X_{12})' to have either a 'Yes' or 'No' status. Accordingly, X_{12} became 'Yes' when the demolisher's workflow uncertainties increased by 3.41%: when it decreased by 15.88%, X_{12} became 'No' (i.e., when nothing changed in other epistemic uncertainties).

Table 7.8 shows that when the meso-level uncertainty of the demolisher had a 'Yes' status (i.e., in the worst-case Scenario A) and a 'No' status (i.e., in the best-case Scenario B), the utility value of QA decreased by 5.28% and increased by 12.43%, respectively. On the other hand, when the meso-level uncertainty of the waste processor had a 'Yes' status (i.e., in the worst-case Scenario A) and a 'No' status (i.e., in the best-case Scenario B), the utility value of QA decreased by 15.25% and increased by 71.07%, respectively. These findings emphasised that the utility value of QA was increasing in larger percentages in the best-case Scenario B than in the worst-case Scenario A. Moreover, the changes in the utility value of QA due to the waste processor's meso-level uncertainty were more than the changes caused by the demolisher's meso-level uncertainty. When considering Scenario C, that is, after implementing all current IPMs by the demolisher and waste processor, the utility value of QA increased by 6.33% and 26.55%, respectively. However, compared to the percentages in Scenario B, internal stakeholders, especially the waste processor (WP1), could undertake IPMs more effectively in response to their meso-level uncertainties for QA to reach their best-case level.

Table 7.8. Analysis of the effect of meso-level uncertainties of each of the demolisher and waste processor on QA in Case I

Observed variables	Focused variable	Prior marginal probability/ utility value	Without IPMs				With IPMs	
			Worst-case Scenario A (Status =Yes)		Best-case Scenario B (Status = No)		Scenario C - With IPMs that were currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Meso-level uncertainties								
- Demolisher's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8057	0.8245	2.34%	0.7614	-5.50%	0.7832	-2.80%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.7698	0.7703	0.08%	`0.7684	-0.18%	0.7691	-0.09%
	QA in RLSCs of DW	0.2095	0.1985	-5.28%	0.2356	12.43%	0.2228	6.33%
- Waste processor's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8057	0.8332	3.41%	0.6778	-15.88%	0.8057	0.00%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.7698	0.8082	5.00%	0.5905	-23.29%	0.6379	-17.14%
	QA in RLSCs of DW	0.2095	0.1776	-15.25%	0.3585	71.07%	0.2652	26.55%

7.3.1.4.3 Analysis of the effect of micro-level uncertainties of each of the demolisher and waste processor on QA in RLSCs of DW

Table 7.9 shows the effect of micro-level uncertainties (observed variables) on the workflow uncertainties of each of the demolisher and waste processor and QA in Case II (focused variables). In the BBN-based conceptual model, all the remaining micro-level uncertainties were propagated towards workflow uncertainties and directly connected with QA in RLSCs of DW. It therefore became necessary to identify the effect of the remaining epistemic uncertainties on workflow uncertainties that appeared under the micro-level category; thus, they were considered 'focused variables'. As shown in Table 7.9, in the worst-case Scenario A, that is, when the micro-level uncertainties of each of the demolisher and waste processor had a 'Yes' status, the prior marginal probabilities of their corresponding workflow uncertainties increased by 9.79% and 17.13%, respectively. On the other hand, in the best-case Scenario B, that is, when the micro-level uncertainties of each of the demolisher and waste processor had a 'No' status, the prior marginal probabilities of workflow uncertainties reduced by 32.46% and 33.70%, respectively. However, in Scenario C, after implementing all current IPMs of each of the demolisher and waste processor in response to micro-level uncertainties, the prior marginal probabilities of their corresponding workflow uncertainties had reduced by 13.69% and 14.43%, respectively. With these findings, it was evident that even though a considerable difference was found between the increments in the prior marginal probabilities of workflow uncertainties between the demolisher and waste processor in Scenario A, such a gap could not be observed in the reductions in Scenarios B and C.

As shown in Table 7.9, the demolisher's micro-level uncertainties slightly increased the prior marginal probability of the waste processor's workflow uncertainties in Scenario A by 0.32% while reducing it in both Scenarios B and C by 1.06% and 0.45%, respectively. On the other hand, the prior marginal probabilities of workflow uncertainties of the demolisher increased by 0.01% and decreased by 0.05% in Scenarios A and B, while nothing had changed in Scenario C. These findings emphasised that the micro-level uncertainties of each of the demolisher and waste processor did not strongly influence each other's workflow uncertainties. Notably, the waste processor's micro-level uncertainties exerted a lower impact on the demolisher's workflow uncertainties.

Table 7.9. Analysis of the effect of micro-level uncertainties of each of the demolisher and waste processor on QA in Case I

Observed variables	Focused variables	Prior marginal probability/ utility value	Without IPMs				With IPMs	
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C – With IPMs that were currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Micro-level uncertainties (except workflow uncertainties)								
- Demolisher's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8057	0.8846	9.79%	0.5442	-32.46%	0.6954	-13.69%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.7698	0.7722	0.32%	0.7616	-1.06%	0.7663	-0.45%
	QA in RLSCs of DW	0.2095	0.1632	-22.12%	0.3633	73.38%	0.2744	30.94%
- Waste processor's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8054	0.8054	0.01%	0.8058	0.05%	0.8057	0.00%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.7698	0.9016	17.13%	0.5104	-33.70%	0.6587	-14.43%
	QA in RLSCs of DW	0.2095	0.1541	-26.48%	0.3189	52.18%	0.2564	22.35%

According to the BBN-based conceptual model (see Figure 7.1), the waste processor's micro-level uncertainties did not affect the demolisher's workflow uncertainties. Therefore, the prior marginal probability of the demolisher's workflow uncertainties had not changed in Scenario C, that is, after implementing all current IPMs in response to the waste processor's micro-level uncertainties. However, in Scenarios A and B, the percentages of deviation in prior marginal probabilities of the demolisher's workflow uncertainties indicated how much of its prior marginal probability should change to cause the micro-level uncertainties of the waste processor to have either a 'Yes' or 'No' status.

When the micro-level uncertainties of the demolisher were in the respective status of 'Yes' and 'No', the utility value of QA decreased by 22.12% and increased by 73.38%, respectively. In contrast, when the waste processor's micro-level uncertainties had the respective status of 'Yes' and 'No', the utility value of QA decreased by 26.48% and increased by 52.18%, respectively. These findings underlined the point that the utility value of QA in the best-case scenario increased in larger percentages than the reduction percentages decreased in the worst-case scenario. Notably, even if the reductions in the utility value of QA in the worst-case Scenario A were nearly the same for both the demolisher and waste processor, a significant deviation occurred in the increments in the best-case Scenario B. Accordingly, the absence of the demolisher's micro-level uncertainties (i.e., in the best-case Scenario B) increased the utility value of QA more than the increment due to the waste processor's micro-level uncertainties. When considering Scenario C, the utility value of QA increased by 30.94% and 22.35% after all current IPMs were implemented by the demolisher and waste processor, respectively. However, compared to the percentages in Scenario B, both the demolisher and waste processor could effectively undertake IPMs in response to their micro-level uncertainties to reach their best-case level.

7.3.1.4.4 Scenarios A, B and C: Analysis of the effect of macro-, meso- and micro-level uncertainties on QA in RLSCs of DW

Table 7.10 shows the effect of macro-, meso- and micro-level uncertainties of the demolisher and waste processor (observed variables) on the utility value of QA in Case I (focused variable). In the worst-case Scenario A (status = Yes), the highest reduction in the utility value of QA was due to macro-level uncertainties (53.35%), followed by micro- (48.75%) and then meso-level (19.82%) uncertainties. On the other

hand, in the best-case Scenario B (status = No), the absence of micro-level uncertainties increased the utility value of QA by a greater percentage than was the case with macro- and meso-level uncertainties. However, in Scenario B, the increment in the utility value of Q due to the absence of macro-level uncertainties (124.33%) was slightly lower than the increment due to micro-level uncertainties (126.11%). With these findings, it became evident that macro-level uncertainties were more essential due to their presence and absence decreasing and increasing the utility value of QA more than the other two types of epistemic uncertainties.

Table 7.10. Analysis of the effect of macro-, meso- and micro-level uncertainties on QA in Case I

Observed variables	Focused variable	Utility value	Without IPMs				With IPMs	
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C – With IPMs that were currently implemented	
			Posterior marginal probability/ utility value	Differ-ence	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Differ-ence
Macro-level uncertainties	QA in RLSCs of DW	0.2095	0.0977	-53.35%	0.4700	124.33 %	0.4291	104.77 %
Meso-level uncertainties			0.1680	-19.82%	0.3926	87.36%	0.2785	32.91%
Micro-level uncertainties (except workflow uncertainties)			0.1074	-48.75%	0.4738	126.11 %	0.3215	53.43%

After implementing all current IPMs in response to each of the macro-, meso- and micro-level uncertainties (i.e., in Scenario C), Case I experienced the highest increment in the utility value of QA due to macro-level uncertainties (104.77%). However, as in Scenario B, the highest increment in the utility value of QA could be achieved by avoiding micro-level uncertainties. Yet, after implementing IPMs in response to micro-level uncertainties, Case I was only able to increase the utility value of QA by 53.43%, which was less than half of the increment percentage in the best-case scenario. Furthermore, it was also found that even if the utility value of QA could be increased by 87.36% through addressing the meso-level uncertainties, IPMs of Case I, which were undertaken in response to meso-level uncertainties, were only able to increase the utility value of QA by 32.91%. It became evident in this analysis that the IPMs undertaken by Case I in response to the macro-level uncertainties were more effective; thus, they succeeded in enhancing QA in the supply chain more than the other IPMs. It was also

worth noting that internal stakeholders in Case I should search for more opportunities to increase QA in their supply chain by enhancing the effectiveness of the IPMs that they undertook in response to micro- and meso-level uncertainties.

7.4 Within-Case Analysis – Case Study II

As with participants in Case I, focus group participants in Case II were provided with the BBN-based conceptual model (see Chapter 6, Figure 6.16) and an explanation of the process and purpose of developing the conceptual model. They were then asked to indicate the IPMs they had undertaken in their supply chain in response to their epistemic uncertainties. Unlike Case I, the participants representing demolishing (D2) and waste processing (WP2) organisations in Case II confirmed that they were undertaking all but five of the IPMs, as shown in Table 7.11. Participants were asked to fill in the given conditional probability tables (CPTs) collaboratively based on the context of their supply chain. When filling in the CPTs, which included the IPMs that Case I was not undertaking, participants were instructed to assume the probability of each epistemic uncertainty if those IPMs were undertaken. The results of the propagation analysis based on the probability elicitation of these participants are presented in the next subsection.

Table 7.11. IPMs undertaken in Case II

Organisation in the case		IPM	Whether undertaking (√) or not (X)
Demolition organisation (D2)	IPM_1	Rules and programs	√
	IPM_2	Planning and goal setting	√
	IPM_3	Business partnering	X
	IPM_4	Collection of building documents and asbestos registers	√
	IPM_5	Site visits/pre-demolition audits	√
	IPM_7	Performance evaluation of sub-contractors	√
	IPM_9	Forming contracts	√
	IPM_{11}	Investment in technologies	√
	IPM_{12}	Group meetings	√
	IPM_{13}	Hierarchical referral	√
	IPM_{14}	Incorporation of self-contained groups	√
	IPM_{15}	Creation of slack resources	√
Waste processing organisation (WP2)	IPM_1	Rules and programs	√
	IPM_2	Planning and goal setting	√
	IPM_3	Business partnering	X
	IPM_6	Creation of integrator roles	X
	IPM_8	Waste acceptance criteria/gate fees	√
	IPM_9	Forming contracts	X

	IPM_{10}	Creation of slack resources	√
	IPM_{11}	Investment in technologies	√
	IPM_{12}	Group meetings	√
	IPM_{13}	Hierarchical referral	√
	IPM_{14}	Incorporation of self-contained groups	√
	IPM_{15}	Creation of special reports	X

7.4.1 Results of epistemic uncertainties propagation: Key findings

Figure 7.4 presents the refined BBN-based conceptual information processing model for QA in Case II, including the prior marginal probabilities (see Chapter 3, Subsection 3.5.2.3) of each epistemic uncertainty (with no IPMs implemented). As shown in Figure 7.4, internal stakeholders in Case II (i.e., the demolisher and waste processor) experienced a value of 0.1120 satisfaction for QA in their supply chain when none of the IPMs were implemented. 'Mixed waste from demolishers (X_{12})' was the epistemic uncertainty with the highest marginal probability of occurring at 0.9216. 'Workflow uncertainties of the waste processor (X_{16})' (0.8786) had the next highest marginal probability of occurring, followed by 'workflow uncertainties of the demolisher (X_8)' (0.8756). Notably, both these workflow uncertainties were directly linked to 'Y. QA in RLSCs of DW'. On the other hand, 'management of demolisher's sub-contractors (X_4)' had the lowest marginal probability of occurring at 0.5317 among all the epistemic uncertainties.

Figure 7.4 indicates how prior marginal probabilities of epistemic uncertainties were propagated from macro-level uncertainties through meso-level to micro-level uncertainties. When only considering macro-level uncertainties, most of the demolisher's uncertainties were more likely to occur than those of the waste processor. However, when considering meso- and micro-level uncertainties, most of the waste processor's epistemic uncertainties had higher prior marginal probabilities than those of the demolisher. For instance, it was apparent from Figure 7.4 that the waste processor's meso-level uncertainty (i.e., 'mixed waste received from demolishers [X_{12}]') received the highest prior marginal probability among all other epistemic uncertainties, while the lowest was the demolisher's meso-level uncertainty (i.e., 'difficulty in managing demolisher's sub-contractors [X_4]'). Notably, the prior marginal probabilities of most of the waste processor's micro-level uncertainties and the meso-level uncertainty were higher than the macro-level uncertainties; still, some exceptions could be found. However, this trend was not visible among the demolisher's epistemic uncertainties.

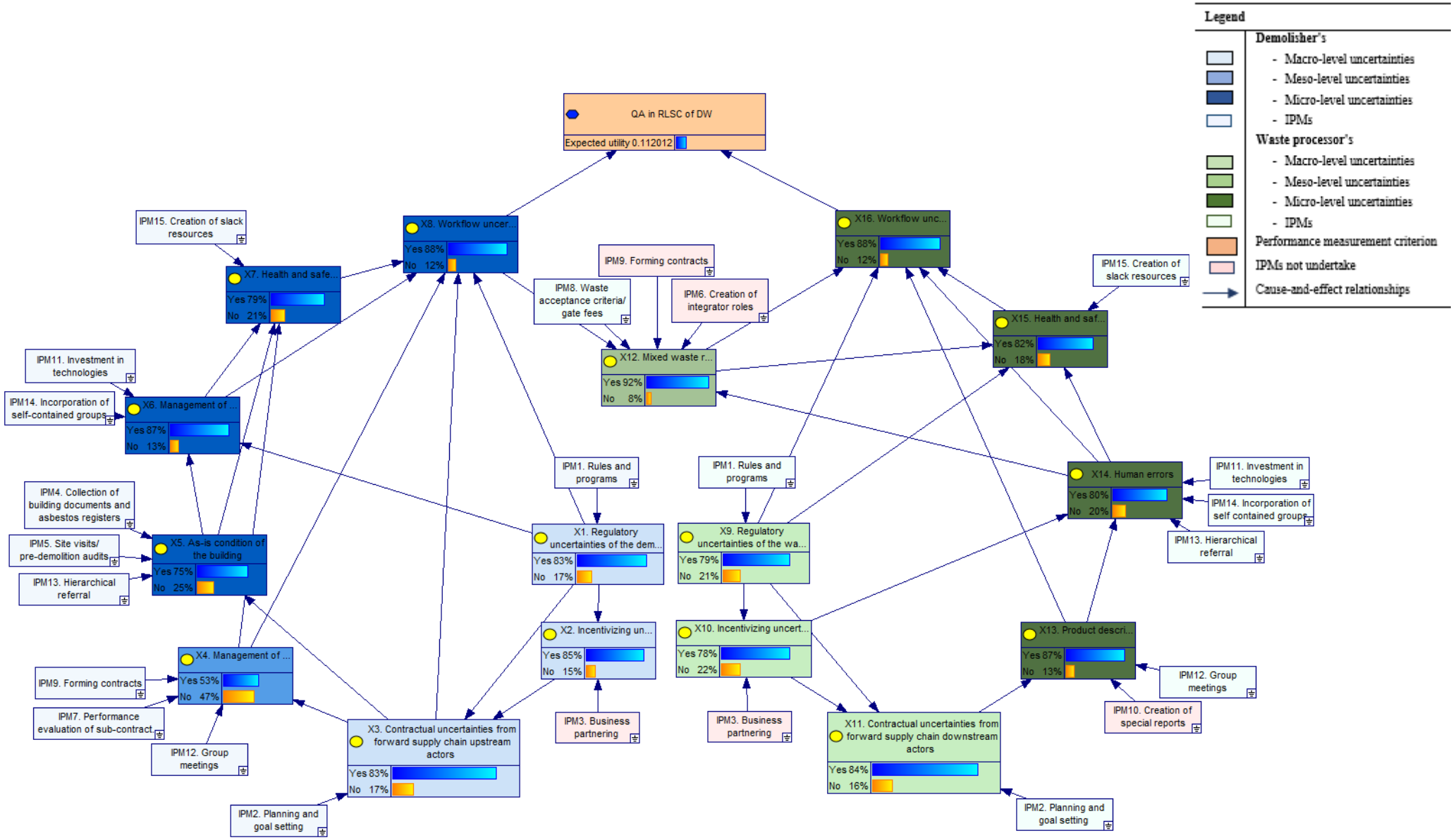


Figure 7.4. Prior marginal probabilities of the epistemic uncertainties in Case II (with no IPMs implemented)

The prior marginal probabilities shown in Figure 7.4 only reflected the impact of uncertainty propagation on QA in Case II before undertaking any of the IPMs. In addition, the BBN-based conceptual model could provide a holistic understanding of information processing for QA in Case II, with this explained through the different analyses discussed in the following subsections.

7.4.1.1 Sensitivity analysis

Figure 7.5 shows the sensitivity analysis of the model with findings from Case II. The vertical axis of the diagram, which lies at 0.1120, indicates the utility value of QA at the prior marginal probabilities of the epistemic uncertainties. The length of a bar specifies the adjusted utility values of QA upon the change between the two extreme states of the cause variables, that is, 'Yes' and 'No' status, as explained in Subsection 7.3.1. Therefore, the bar's length represents how sensitive QA is towards each epistemic uncertainty in Case II.

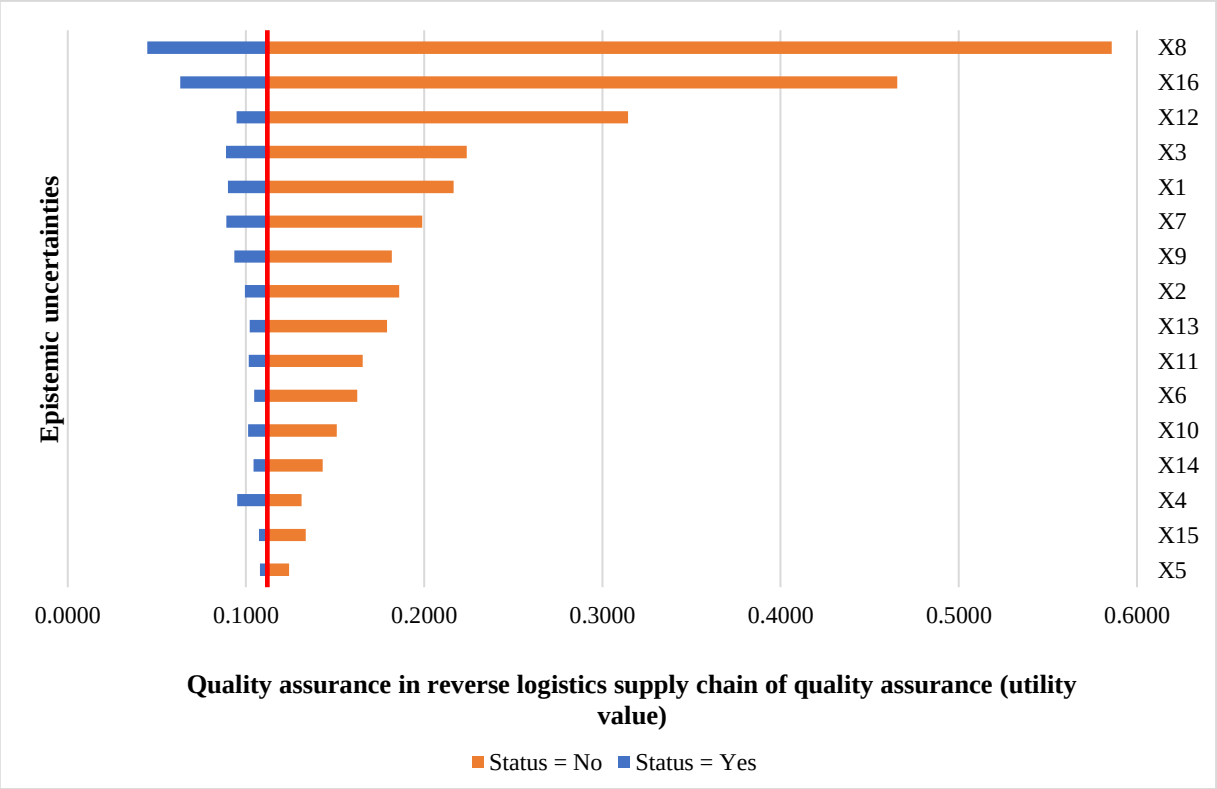


Figure 7.5. Sensitivity analysis of epistemic uncertainties in Case II

As shown in Figure 7.5, 'workflow uncertainties of the demolisher (X_8)' had the longest bar. The utility value of QA could change from 0.0447 to 0.5859 upon the status change of X_8 from 'Yes' to 'No', respectively. This means that QA in Case II was highly

sensitive to changing the prior marginal probability of 'workflow uncertainties of the demolisher (X_8)'. 'Workflow uncertainties of the waste processor (X_{16})' was the second-highest epistemic uncertainty to which QA in Case II was most sensitive. Accordingly, due to 'workflow uncertainties of the waste processor (X_{16})', the utility value of QA could change from 0.0631 (given X_{16} = Yes) to 0.4656 (given X_{16} = No). Furthermore, QA was most sensitive to epistemic uncertainties, such as 'mixed waste from demolishers (X_{12})'; 'contractual uncertainties from FSC-upstream actors (X_3)'; and 'regulatory uncertainties of the demolisher (X_1)' which appeared at the third, fourth and fifth places in the tornado graph. Four of the top seven epistemic uncertainties, to which QA was highly sensitive, were the demolisher's epistemic uncertainties.

As shown in Figure 7.5, all macro-level uncertainties were concentrated in the middle of the tornado graph. This indicated that QA in Case II was moderately sensitive to macro-level uncertainties. It was found that QA was more sensitive to the demolisher's macro-level uncertainties than to those of the waste processor. Furthermore, the meso-level uncertainty of the waste processor (i.e., 'mixed waste received from demolishers (X_{12})') was more influential on the utility value of QA in Case II than that of the demolisher' (i.e., 'management of the demolisher's sub-contractors (X_4)'). It was apparent from Figure 7.5 that 'management of the demolisher's sub-contractors (X_4)' appeared as the third-lowest uncertainty to which the utility value of QA was most sensitive. Most micro-level uncertainties, such as ''as-is' condition of the building (X_5)'; 'health and safety concerns of the waste processor (X_{15})'; and 'human errors (X_{14})' appeared at the bottom levels of the tornado graph, indicating that the utility value of QA in Case II was less sensitive to them. Figure 7.5 shows that the reduction of the utility value of QA with epistemic uncertainties having a 'Yes' status was comparatively lower than its increment with a 'No' status for each uncertainty. Given this point, it was understood that if appropriate IPMs were undertaken, especially those aiming to reduce the marginal probabilities of the occurrence of uncertainties to which the utility value of QA was highly sensitive, a great improvement in the utility value of QA could be experienced in Case II.

7.4.1.2 Root cause analysis

As explained in Subsection 7.4.1.1, the utility value of QA in Case II was highly sensitive to workflow uncertainties of the demolisher and waste processor (i.e., X_8 and X_{16}). As X_8 and X_{16} uncertainties were directly linked to the utility node (see BBN-

based conceptual model in Figure 7.4), the utility value of QA's high sensitivity to them was admissible. Given this point, the current subsection aims to identify the critical path of epistemic uncertainties that augments workflow uncertainties through root cause analysis, while adhering to the concept of back-propagation (see Chapter 3, Subsection 3.5.2.3.3).

When 'workflow uncertainties of the demolisher (X_8)' = Yes (i.e., 100% or 1.000), 'management of contaminated/hazardous substances (X_6)' was the most likely cause to present (i.e., a 'Yes' status) with its probability of 0.8847. This emphasised that managing contaminated/hazardous substances was the root cause that significantly caused workflow uncertainties in Case II. The next most likely root cause for 'management of contaminated/hazardous substances (X_6)' was 'regulatory uncertainties of the demolisher (X_1)' which had a probability of occurrence of 0.8415, when X_6 (Yes) = 100%. According to the BBN-based conceptual model (see Figure 7.4), no further epistemic uncertainties were attached to regulatory uncertainties. Therefore, the critical path that caused demolishers' workflow uncertainties was short and only comprised X_6 and X_1.

Similarly, when 'workflow uncertainties of the waste processor (X_{16})' = Yes (i.e., 100% or 1.000), 'mixed waste from demolishers (X_{12})' was the most likely cause to present (i.e., a 'Yes' status) with its probability of 0.9406. 'Workflow uncertainties of the demolisher (X_8)' was the next most significant root cause of 'mixed waste from demolishers (X_{12})'. It was found that when the prior marginal probability of 'workflow uncertainties of the demolisher (X_8)' was 0.8951, 'mixed waste from demolishers (X_{12})' became 'Yes'. After that, as explained in the above paragraph, 'management of contaminated/ hazardous substances (X_6)' and 'regulatory uncertainties of the demolisher (X_1)', sequentially, were the root causes of 'workflow uncertainties of the demolisher (X_8)'. After consolidating these findings, the critical path of epistemic uncertainties for QA in Case II was as depicted in Figure 7.6.

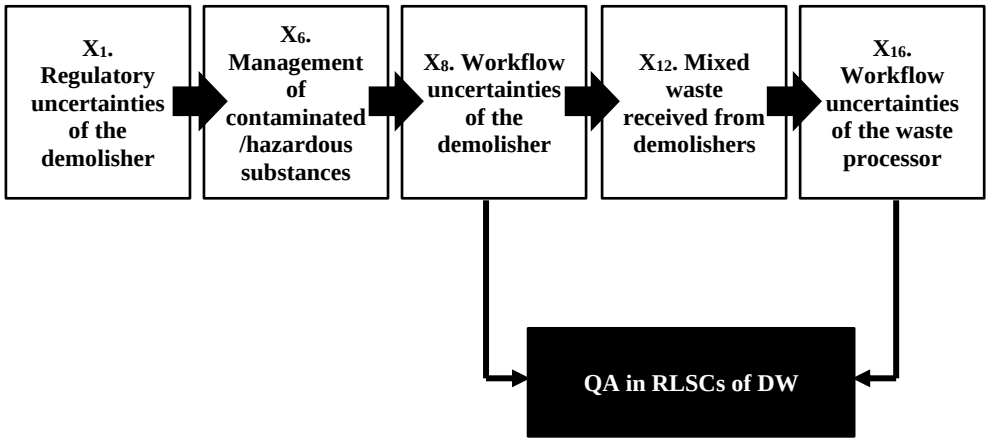


Figure 7.6. Critical path of epistemic uncertainties of Case II

7.4.1.3 Analysis of IPMs

This section observes the effect of each and all IPMs on the prior marginal probabilities of epistemic uncertainties and the utility value of QA in Case II.

7.4.1.3.1 Analysis of change of the prior marginal probabilities of each epistemic uncertainty and the utility value of QA with implementation of <u>each</u> IPM

The current subsection discusses the effectiveness of IPMs undertaken by Case II in reducing prior marginal probabilities of epistemic uncertainties and increasing QA in the RLSC. This subsection also discusses the amount of reduction in epistemic uncertainties that would result if the demolisher and waste processor in Case II implemented the IPMs that they were not undertaking (see Section 7.4). Table 7.12 shows how the prior marginal probabilities of each epistemic uncertainty and the utility value of QA fluctuated depending on the combined and separate implementations of IPMs that were (or were not) currently undertaken.

As shown in Table 7.12, from the demolisher's perspective, the highest reduction in prior marginal probability (i.e., 57.61%) and the increment in the utility value of QA (i.e., 53.79%) were due to the development of 'rules and programs (IPM_1)', specifically in response to 'regulatory uncertainties (X_1)'. The second highest reduction in the prior marginal probability (i.e., 39.05%) and the utility value of QA increment (31.79%) were in 'contractual uncertainties from FSC-upstream actors (X_3)' due to 'planning and goal setting (IPM_2)'. The third, fourth and fifth-highest reductions in prior marginal probabilities of the demolisher's epistemic uncertainties (i.e., 29.68%, 28.43% and 26.06%, respectively) were due to 'forming contracts (IPM_9)'; 'collection of building documents and asbestos registers (IPM_4)'; and 'creation of slack resources (IPM_{15})', respectively. However, the increments in the utility value of QA due to 'forming

contracts (IPM_9)' and 'collection of building documents and asbestos registers (IPM_4)' were significantly lower (i.e., less than 2%) when compared to the increment in the utility value of QA created by 'creation of slack resources (IPM_{15})' (i.e., 19.60%). From the demolisher's perspective, the lowest increment in the utility value of QA was due to 'hierarchical referral (IPM_{13})' (i.e., 0.09%) which also reduced the prior marginal probability of ''as-is' condition of the building (X_5)' by only 1.33%. 'Group meetings (IPM_{12})' created the next lowest increment in the utility value of QA (i.e., 0.29%) by decreasing 5.64% of the prior marginal probability of 'management of the demolisher's sub-contractors (X_4)'. Table 7.12 outlines the increased percentages of the utility value of QA due to most demolishers' IPMs being significantly lower than the decreased percentages of prior marginal probabilities of corresponding epistemic uncertainties. This indicates that, even if most IPMs succeeded in reducing prior marginal probabilities of epistemic uncertainties with greater percentages, their effect on increasing the utility value of QA was comparatively low.

As from the demolisher's perspective, from the waste processor's perspective, 'rules and programs (IPM_1)' was the most effective IPM which significantly reduced the prior marginal probability of 'regulatory uncertainties (X_9)' by 58.78% and increased the utility value of QA by 36.60%. Even though the second-highest reduction in the prior marginal probability (i.e., 38.87%) was due to 'planning and goal setting (IPM_2)', this IPM only succeeded in increasing the utility value of QA by 2.78%. In contrast, 'waste acceptance criteria/gate fees (IPM_8)' increased the utility value of QA by 22.82%, while reducing the prior marginal probability of its connected epistemic uncertainty (i.e., 'mixed waste from demolishers [X_{12}]') by 22.82%, which was the third-highest reduction in prior marginal probabilities. As from the demolisher's perspective, from the waste processor's perspective, the lowest reduction of prior marginal probability (i.e., 2.85%) and thereby the lowest increment in the utility value of QA (i.e., 0.67%) were due to 'hierarchical referral (IPM_{13})'. 'Investment in technologies (IPM_{11})' created the next lowest increment in the utility value of QA (i.e., 1.09%) by decreasing 4.64% of the prior marginal probability of 'human errors (X_{14})'.

Table 7.12. Effect of each IPM on prior marginal probabilities of epistemic uncertainties and QA in Case II

	Epistemic uncertainties and corresponding IPMs	Prior marginal probabilities (X_y = Yes)					QA in RLSCs of DW (utility value)				
			With IPM(s)					With IPM(s)			
		Without IPM(s)	IPM(s) that were currently implemented	Difference	IPM(s) that were not currently implemented	Difference	Without IPM(s)	IPM(s) that were currently implemented	Difference	IPM(s) that were not currently implemented	Difference
Demolition organisation (D2)	**X_1. Regulatory uncertainties of the demolisher**										
	Rules and programs	0.8256	0.3500	-57.61%	-	-	0.1120	0.1723	53.79%	-	-
	X_2. Incentivising uncertainties of the demolisher										
	Business partnering	0.8541	-	-	0.7698	-9.87%	0.1120	-	-	0.1128	0.71%
	X_3. Contractual uncertainties from FSC-upstream actors										
	Planning and goal setting	0.8285	0.5049	-39.05%	-	-	0.1120	0.1476	31.79%	-	-
	X_4. Management of demolisher's sub-contractors										
	Forming contracts	0.5317	0.3739	-29.68%	-	-	0.1120	0.1135	1.31%	-	-
	Performance evaluation of sub-contractors	0.5317	0.4483	-15.69%	-	-	0.1120	0.1129	0.78%	-	-
	Group meetings	0.5317	0.5017	-5.64%	-	-	0.1120	0.1123	0.29%	-	-
	All IPCs	0.5317	0.1380	-74.05%	-	-	0.1120	0.1160	3.60%	-	-
	X_5. 'As-is' condition of the building										
	Collection of building documents and asbestos registers	0.7497	0.5366	-28.43%	-	-	0.1120	0.1142	1.96%	-	-
	Site visits/pre-demolition audits	0.7497	0.5606	-25.22%	-	-	0.1120	0.1140	1.74%	-	-
	Hierarchical referral	0.7497	0.7397	-1.33%	-	-	0.1120	0.1121	0.09%	-	-
	All IPCs	0.7497	0.1886	-74.85%	-	-	0.1120	0.1178	5.14%	-	-
	X_6. Management of contaminated/hazardous substances										
	Investment in technologies	0.8710	0.8099	-7.01%	-	-	0.1120	0.1147	2.40%	-	-
	Incorporation of self-contained groups	0.8710	0.7076	-18.75%	-	-	0.1120	0.1188	6.10%	-	-
	All IPCs	0.8710	0.5671	-34.89%	-	-	0.1120	0.1250	11.55%	-	-
	X_7. Health and safety concerns of the demolisher										
	Creation of slack resources	0.7908	0.5847	-26.06%	-	-	0.1120	0.1340	19.60%	-	-

	Epistemic uncertainties and corresponding IPMs	Prior marginal probabilities (X_y = Yes)					QA in RLSCs of DW (utility value)				
			With IPM(s)					With IPM(s)			
		Without IPM(s)	IPM(s) that were currently implemented	Difference	IPM(s) that were not currently implemented	Difference	Without IPM(s)	IPM(s) that were currently implemented	Difference	IPM(s) that were not currently implemented	Difference
Waste processing organisation (WP2)	**X_9. Regulatory uncertainties of the waste processor**										
	Rules and programs	0.7895	0.3254	-58.78%	-	-	0.1120	0.1530	36.60%	-	-
	X_{10}. Incentivising uncertainties of the waste processor										
	Business partnering	0.7813	-	-	0.7303	-6.53%	0.1120	-	-	0.1122	0.17%
	X_{11}. Contractual uncertainties from FSC-downstream actors										
	Planning and goal setting	0.8353	0.5106	-38.87%	-	-	0.1120	0.1151	2.78%	-	-
	X_{12}. Mixed waste received from demolishers										
	Waste acceptance criteria/gate fees	0.9216	0.6274	-31.92%	-	-	0.1120	0.1376	22.82%	-	-
	Forming contracts	0.9216	-	-	0.8147	-11.60%	0.1120	-	-	0.1213	8.30%
	Creation of integrator roles	0.9216	-	-	0.8365	-9.24%	0.1120	-	-	0.1194	6.60%
	All IPCs	0.9216	0.6274	-31.92%	0.3848	-58.24%	0.1120	0.1376	22.82%	0.1586	41.62%
	X_{13}. Product description complexities										
	Creation of special reports	0.8707	-	-	0.5504	-36.79%	0.1120	-	-	0.1334	19.12%
	Group meetings	0.8707	0.7735	-11.17%	-	-	0.1120	0.1185	5.79%	-	-
	All IPCs	0.8707	0.7735	-11.17%	0.4405	-49.41%	0.1120	0.1185	5.79%	0.1408	25.69%
	X_{14}. Human errors										
	Investment in technologies	0.7995	0.7624	-4.64%	-	-	0.1120	0.1132	1.09%	-	-
	Hierarchical referral	0.7995	0.7767	-2.85%	-	-	0.1120	0.1128	0.67%	-	-
	Incorporation of self-contained groups	0.7995	0.6962	-12.92%	-	-	0.1120	0.1153	2.92%	-	-
	All IPCs	0.7995	0.6010	-24.82%	-	-	0.1120	0.1181	5.42%	-	-
	X_{15}. Health and safety concerns of the waste processor										
	Creation of slack resources	0.8183	0.7378	-9.84%	-	-	0.1120	0.1133	1.17%	-	-

It was evident from Table 7.12 that the reductions in prior marginal probabilities of epistemic uncertainties due to the execution of IPMs were within the same range in both the demolisher and waste processor cases. However, increments in the utility value of QA due to the demolisher's IPMs were comparatively higher than increments created by the waste processor's IPMs. For instance, as shown in Table 7.12, the reductions in prior marginal probabilities of contractual uncertainties due to 'planning and goal setting (IPM_2)' of both the demolisher (X_3) and waste processor (X_{11}) were nearly the same. However, the increment in the utility value of QA due to the demolisher's planning and goal setting (i.e., 31.79%) was 10 times more than the increment created by the waste processor's planning and goal setting (i.e., 2.78%). Table 7.12 also shows that when the IPMs were considered separately, most of them reduced the prior marginal probabilities and increased the utility value of QA by lower percentages. However, when they were implemented in combination (with more than one IPM per epistemic uncertainty present), comparatively, a higher percentage of reduction in prior marginal probabilities and increment in the utility value of QA could be observed, as shown in Table 7.12. For instance, 'investment in technologies (IPM_{11})' reduced only 7.01% of the prior marginal probability of 'management of contaminated/hazardous substances (X_6)' and thereby increased the utility value of QA by 2.40%. Similarly, 'incorporation of self-contained groups (IPM_{14})' reduced 18.75% of the prior marginal probability of the same epistemic uncertainty while increasing only 6.10% of the utility value of QA. When both these IPMs were implemented, the prior marginal probability of epistemic uncertainty was reduced by 34.89% while the utility value of QA was increased by 11.55%. As with Case I, Case II also provided evidence that most IPMs that were less rich and more impersonal (e.g., rules and programs, planning and goal setting) were more effective when implemented separately than IPMs that were richer and more personal (e.g., incorporation of self-contained groups, investment in technologies).

Of all 15 IPMs, as explained in Section 7.4, the following IPMs were not implemented in Case II: business partnering (IPM_3 of both demolisher and waste processor); forming contracts (IPM_9 of waste processor); creation of integrator roles (IPM_6 of waste processor); and creation of special reports (IPM_{10} of waste processor). Table 7.12 shows the reductions in prior marginal probabilities of epistemic uncertainties and corresponding increments in the utility value of QA that could have been achieved in

the presence of IPMs that were not currently implemented. Accordingly, 'business partnering (IPM_3)' could have reduced 9.87% of the prior marginal probability of 'incentivising uncertainties of the demolisher (IPM_2)', while increasing only 0.71% of the utility value of QA. Similarly, from the waste processor's perspective, 'business partnering (IPM_3)' could have reduced the prior marginal probability of 'incentivising uncertainties (IPM_{10})' by 6.53% and increased the utility value of QA by 0.17%. It was also observed that implementing some IPMs together with the current IPMs could have significantly reduced prior marginal probabilities of epistemic uncertainties and thereby increased the utility value of QA. For instance, if 'forming contracts (IPM_9)' and 'creation of integrator roles (IPM_6)' were implemented with 'waste acceptance criteria/gate fees (IPM_8)', the reduction in the prior marginal probability of 'mixed waste from demolishers (X_{12})' could have been increased from 34.82% to 58.24%. At the same time, the increment in the utility value of QA could have increased from 26.16% to 41.62%. Similarly, if 'creation of special reports (IPM_{10})' was undertaken with 'group meetings (IPM_{12})', the prior marginal probability of 'product description complexities (X_{13})' could have been reduced by 49.41%, that is, 38.24% more than when 'creation of special reports (IPM_{10})' was absent. Concurrently, the utility value of QA could have increased by 25.69% which was 19.51% more than the status quo scenario. Given this discussion, it is understood that Case II could have significantly increased the utility value of QA by implementing the IPMs that were not being currently undertaken.

7.4.1.3.2 Analysis of change of the prior marginal probabilities of each epistemic uncertainty and the utility value of QA with implementation of <u>all</u> IPMs

As explained in Chapter 6, Subsection 6.4.2, the IPMs were positioned in the BBN-based conceptual model (see Figure 7.4) in such a way that they could exert a significant influence on QA. Table 7.12 shows the effect of each IPM on reducing the prior marginal probabilities of their corresponding epistemic uncertainties and, therefore, the utility value of QA in Case II. However, due to the cause-and-effect relationships, each IPM also reduced the prior marginal probabilities of other epistemic uncertainties, directly or indirectly, as related to the uncertainty linked with the IPM. Accordingly, Table 7.13 outlines how implementing all the IPMs in Case II reduced the prior marginal probability of each epistemic uncertainty and increased the utility value of QA. Table 7.13 also shows how the prior marginal probabilities of epistemic uncertainties, and the utility value of QA could have been reduced or increased,

respectively, depending upon the implementation of IPMs not currently undertaken in Case II (see Section 7.4).

According to Table 7.13, Case II increased the utility value of QA from 0.1120 to 0.3331 by undertaking all the current IPMs. Of all 16 epistemic uncertainties, the prior marginal probabilities of only seven epistemic uncertainties were reduced by more than 50% after implementing all the current IPMs. Among all epistemic uncertainties, the ‘‘as-is’ condition of the building (X_5)’ was the epistemic uncertainty with the highest reduction of prior marginal probabilities, decreasing by 83.62%. This highlighted that all the IPMs undertaken by Case II were most effective in reducing the epistemic uncertainties related to the ‘‘as-is’ condition of the building (X_5)’. ‘Management of the demolisher’s sub-contractors (X_4)’ received the next highest reduction (i.e., 80.97%) in prior marginal probabilities after implementing all the current IPMs, followed by ‘management of contaminated/hazardous substances (X_6)’ (67.21%). Notably, the three uncertainties with the highest reductions in prior marginal probabilities were epistemic uncertainties of the demolisher. It was also apparent from Table 7.13 that the reductions in prior marginal probabilities were higher in the demolisher’s epistemic uncertainties than in those of the waste processor.

Table 7.13. Effect of <u>all</u> IPMs on prior marginal probabilities of epistemic uncertainties and QA in Case II

	Epistemic uncertainty	Status	Prior marginal probability					Increment in the difference [X-Y]
			Without IPMs	With IPMs that were currently implemented	Difference (%) [X]	With IPMs that were not currently implemented	Difference (%) [Y]	
X_1	Regulatory uncertainties of the demolisher	**Yes**	0.8256	0.3500	-57.61%	0.3500	-57.61%	0.00%
X_2	Incentivising uncertainties of the demolisher	**Yes**	0.8541	0.5925	-30.63%	0.4115	-51.82%	21.19%
X_3	Contractual uncertainties from FSC-upstream actors	**Yes**	0.8285	0.3023	-63.51%	0.2993	-63.87%	0.36%
X_4	Management of demolisher’s sub-contractors	**Yes**	0.5317	0.1012	-80.97%	0.1010	-81.01%	0.04%
X_5	‘As-is’ condition of the building	**Yes**	0.7497	0.1228	-83.62%	0.1224	-83.67%	0.05%
X_6	Management of contaminated/ hazardous substances	**Yes**	0.8710	0.2855	-67.21%	0.2855	-67.23%	0.02%
X_7	Health and safety concerns of the demolisher	**Yes**	0.7908	0.4662	-41.04%	0.4662	-41.05%	0.01%
X_8	Workflow uncertainties of the demolisher	**Yes**	0.8756	0.6303	-28.01%	0.6299	-28.06%	0.05%

X_9	Regulatory uncertainties of the waste processor	**Yes**	0.7895	0.3254	-58.78%	0.3254	-58.78%	0.00%
X_{10}	Incentivising uncertainties of the waste processor	**Yes**	0.7813	0.5253	-32.78%	0.4173	-46.59%	13.81%
X_{11}	Contractual uncertainties from FSC-downstream actors	**Yes**	0.8353	0.3282	-60.70%	0.3080	-63.13%	2.43%
X_{12}	Mixed waste received from demolishers	**Yes**	0.9216	0.5597	-39.27%	0.3244	-64.81%	25.54%
X_{13}	Product description complexities	**Yes**	0.8707	0.7238	-16.87%	0.4142	-52.43%	35.56%
X_{14}	Human errors	**Yes**	0.7995	0.5330	-33.33%	0.4208	-47.36%	14.03%
X_{15}	Health and safety concerns of the waste processor	**Yes**	0.8187	0.5405	-33.97%	0.4930	-39.79%	5.82%
X_{16}	Workflow uncertainties of the waste processor	**Yes**	0.8786	0.6381	-27.38%	0.5046	-42.57%	15.19%
Expected utility value of QA			**0.1120**	**0.3331**		**0.3827**		

The lowest reduction in prior marginal probabilities after implementing all IPMs was with 'product description complexities (X_{13})', that is, a reduction of 16.87%. The workflow uncertainties of both the waste processor (X_{16}) and demolisher (X_8) received the next lowest reductions in prior marginal probabilities at 27.38% and 28.01%, respectively. Therefore, due to the execution of current IPMs, the prior marginal probabilities of workflow uncertainties of the demolisher (X_8) and waste processor (X_{16}) were only reduced by less than 30%, even if none of the IPMs were directly attached to them. The incentivising uncertainties of both the demolisher (X_2; 30.63%) and waste processor (X_{10}; 32.78%) also had considerably lower percentages of reduction in prior marginal probabilities compared to the other epistemic uncertainties. After implementing all the current IPMs, from the demolisher's perspective, the reductions in prior marginal probabilities were higher in meso- and most micro-level uncertainties than in macro-level ones. On the other hand, from the waste processor's perspective, the reductions in prior marginal probabilities of most macro-level uncertainties were higher than those in prior marginal probabilities of meso- and micro-level uncertainties.

As outlined in Section 7.4, Case II was not currently undertaking five of the 15 IPMs in the BBN-based conceptual model (see Figure 7.4). Table 7.13 shows the reductions that could have been observed in prior marginal probabilities if Case II had implemented all the IPMs, including those that were not currently undertaken. Similar to the status quo scenario (i.e., without implementing the five IPMs), the ''as-is' condition of the building (X_5)' could have been the epistemic uncertainty with the highest reduction in prior marginal probabilities if all the IPMs were implemented. However, compared to the status quo scenario, only a slight increment (i.e., 0.05%) in the reduction

percentages of prior marginal probabilities was observed in the ‘‘as-is’ condition of the building (X_5)’. Of all the demolisher’s epistemic uncertainties, after implementing the IPMs, including those that were not currently undertaken, only the prior marginal probability of ‘incentivising uncertainties (X_2)’ could be reduced by a higher percentage (i.e., 51.82%) than the status quo scenario (i.e., 30.63%). As ‘business partnering (IPM_3)’ was the only IPM that the demolisher in Case II was not currently undertaking, if it had been undertaken, a significant reduction in the prior marginal probability of incentivising uncertainties could have been observed. Except for incentivising uncertainties, the reduction in prior marginal probabilities of all the remaining demolisher’s epistemic uncertainties could not have been increased by more than 1%, even if all the IPMs were implemented. In contrast, the prior marginal probabilities of most of the waste processor’s epistemic uncertainties could have been reduced by comparatively higher percentages if all the IPMs were implemented. If all the IPMs were implemented, the reductions in prior marginal probabilities of the waste processor’s epistemic uncertainties, such as ‘incentivising uncertainties (X_{10})’; ‘mixed waste received from demolishers (X_{12})’; ‘product description complexities (X_{13})’; ‘human errors (X_{14})’; and ‘workflow uncertainties (X_{16})’, could have been increased by more than 10%. For instance, the prior marginal probability of ‘product description complexities (X_{13})’, which was reduced to 16.87% in the status quo scenario, could have been increased to a reduction of 52.43% if all the IPMs were implemented. Finally, the expected utility value of QA in Case II could have been increased from 0.3331 to 0.3827 by implementing all the IPMs, with this being an increment of 14.89%.

7.4.1.4 Scenario analysis

As explained in Subsection 7.3.1.4, the scenario analysis observed the combined effect on a particular variable(s) (i.e., observed variables) due to the changes in the states of several epistemic uncertainties under different classifications (i.e., focused variables). The results are discussed in the following subsections.

7.4.1.4.1 Analysis of the effect of macro-level uncertainties of each of the demolisher and waste processor on QA in RLSCs of DW

Table 7.14 outlines the analysis of the effect of macro-level uncertainties of each of the demolisher and waste processor (observed variables) on workflow uncertainties and the utility value of QA (focused variables) in Case II. Table 7.14 shows how the focused

variables' posterior marginal probabilities/utility value would change depending on the four different scenarios of each observed variable. Those four scenarios comprise Scenario A – status of the observed variables (Yes); Scenario B – status of the observed variables (No); Scenario C – after implementing current IPMs; and Scenario D – after implementing all the IPMs.

In the worst-case Scenario A, that is, when all the macro-level uncertainties of each of the demolisher and waste processor had a 'Yes' status, the prior marginal probabilities of their corresponding workflow uncertainties increased by 6.76% and 5.75%, respectively. On the other hand, in the best-case Scenario B, that is, when the macro-level uncertainties of each of the demolisher and waste processor had a 'No' status, the prior marginal probabilities of their corresponding workflow uncertainties reduced by 27.23% and 22.20%, respectively. However, in Scenario C, that is, after implementing the IPMs of the demolisher and waste processor in Case II, the prior marginal probabilities of their corresponding workflow uncertainties were reduced by 17.77% and 12.89%, respectively. Let us suppose that all IPMs were undertaken in response to each of the demolisher's and waste processor's macro-level uncertainties, including those not currently being undertaken (i.e., business partnering). In that case, the prior marginal probabilities of their corresponding workflow uncertainties could have been reduced by 17.82% and 13.09%, respectively.

As shown in Table 7.14, when the demolisher's macro-level uncertainties had a 'Yes' status (i.e., in Scenario A), the prior marginal probability of the waste processor's workflow uncertainties (X_{16}) increased by 0.25%. On the other hand, when the demolisher's macro-level uncertainties had a 'No' status, the prior marginal probability of the waste processor's workflow uncertainties (X_{16}) reduced by 1.02%. In Scenario C, it was found that, after implementing the current IPMs in response to the demolisher's macro-level uncertainties, the prior marginal probability of the waste processor's workflow uncertainties was reduced by 0.66%. The same reduction of the prior marginal probability of the waste processor's workflow uncertainties could be found in Scenario D, even after implementing all the IPMs, including those that were not currently undertaken. In contrast to these findings, the prior marginal probability of the demolisher's workflow uncertainties (X_8) remained unchanged despite changes in the waste processor's macro-level uncertainties in all four scenarios.

Table 7.14. Analysis of the effect of macro-level uncertainties of each of the demolisher and waste processor on QA in Case II

Observed variables	Focused variables	Prior marginal probability/ utility value	Without IPMs				With IPMs			
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C – With IPMs that were currently implemented		Scenario D – With all IPMs, including those that were not currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Macro-level uncertainties										
- Demolisher's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8756	0.9348	6.76%	0.6371	-27.23%	0.7199	-17.77%	0.7195	-17.82%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.8786	0.8808	0.25%	0.8696	-1.02%	0.8727	-0.66%	0.8727	-0.66%
	QA in RLSCs of DW	0.1120	0.0800	-28.60%	0.2410	115.19%	0.1962	75.18%	0.1965	75.40%
- Waste processor's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8756	0.8756	0.00%	0.8756	0.00%	0.8756	0.00%	0.8756	0.00%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.8786	0.9291	5.75%	0.6835	-22.20%	0.7646	-12.98%	0.7636	-13.09%
	QA in RLSCs of DW	0.1120	0.0927	-17.25%	0.1866	66.58%	0.1556	38.92%	0.1560	39.25%

These findings emphasised that, even if the demolisher's macro-level uncertainties slightly impacted on the waste processor's workflow uncertainties (X_{16}), this impact could not be found in the demolisher's workflow uncertainties (X_8) despite the waste processor's macro-level uncertainties.

Furthermore, when the macro-level uncertainties of the demolisher had a 'Yes' status, the utility value of QA decreased by 28.60%. On the other hand, the utility value of QA increased by 115.19% when the macro-level uncertainties of the demolisher had a 'No' status. From the waste processor's perspective, when the macro-level uncertainties did not have a 'Yes' or 'No' status, the utility value of QA decreased by 17.25% and increased by 66.58%, respectively. These findings indicated that the utility value of QA in the best-case scenario increased in larger percentages than the percentages of reduction in the worst-case scenario. Notably, a significantly higher increment of 115.19% in the utility value of QA could be achieved with 'No' status for the demolisher's macro-level uncertainties, with this being 48.61% more than the increment when the waste processor's macro-level uncertainties had a 'No' status. After implementing the current IPMs by the demolisher and waste processor, that is, in Scenario C, the utility value of QA was increased by 75.18% and 38.92%, respectively. These percentages could be increased to 75.40% and 39.25% (see Scenario D) if all the IPMs were undertaken in response to the macro-level uncertainties by the demolisher and waste processor in Case II. However, these findings emphasised that, even if all the IPMs were implemented, including those not currently undertaken, the utility value of QA could not have increased significantly more than in the status quo scenario.

7.4.1.4.2 Analysis of the effect of meso-level uncertainties of each of the demolisher and waste processor on QA in RLSCs of DW

Table 7.15 presents the analysis of the effect of meso-level uncertainties (observed variables) on workflow uncertainties of each of the demolisher and waste processor and the utility value of QA (focused variables) in Case II. As shown in Table 7.15, in the worst-case Scenario A, that is, when meso-level uncertainties of each of the demolisher and waste processor had a 'Yes' status, the prior marginal probabilities of corresponding workflow uncertainties increased by 3.58% and 2.06%, respectively. On the other hand, in the best-case scenario, that is, when meso-level uncertainties of each of the demolisher and waste processor had a 'No' status, the prior marginal probabilities of their workflow uncertainties reduced by 4.06% and 24.22%, respectively. With these

results, it became understandable that the prior marginal probabilities of the waste processor's workflow uncertainties could be reduced more than those of the demolisher by implementing effective IPMs in response to its meso-level uncertainty. Accordingly, in Scenario C, that is, after implementing the current IPMs in response to meso-level uncertainties of each of the demolisher and waste processor, the prior marginal probabilities of their workflow uncertainties were reduced by 0.85% and 7.61%, respectively. As explained in Section 7.4, the demolisher in Case II was undertaking all the IPMs in response to its meso-level uncertainty (i.e., management of demolisher's sub-contractors (X_4)). However, the waste processor in Case II was only undertaking 'waste acceptance criteria/gate fees (IPM_8)', one of the three IPMs in the BBN-based conceptual model that could be undertaken in response to its meso-level uncertainty (i.e., 'mixed waste from demolishers (X_{12})'). With this result, Scenario D outlined that the waste processor could have reduced the prior marginal probabilities of its workflow uncertainties by 13.88% which was 6.27% more than the status quo reduction if it implemented all the IPMs in response to its meso-level uncertainty. The demolisher also needed to increase the effectiveness of its IPMs as its current way of undertaking IPMs had reduced its workflow uncertainties by only 0.85%.

When referring to Scenarios A, B, C and D, it was evident that the meso-level uncertainty of the demolisher, that is, 'management of demolisher's sub-contractors (X_4)', slightly impacted on the waste processor's workflow uncertainties (X_{16}). With the demolisher in Case II undertaking all the IPMs in response to its meso-level uncertainty, the waste processor's workflow uncertainties (X_{16}) reduced in the same percentage as in both Scenarios C and D. Due to changes in the status of the waste processor's meso-level uncertainty, fluctuations in the prior marginal probability of the demolisher's workflow uncertainties (X_8) were found in Scenarios A and B but not in Scenarios C and D. As also explained in Subsection 7.3.1.4.2, according to the arrangement in the BBN-based conceptual model, as in Figure 7.4, 'mixed waste received from demolishers (X_{12})' was not affecting but was being affected by the demolisher's workflow uncertainties (X_8). Therefore, in Scenarios C and D, that is, after implementing either current IPMs or all the IPMs (including those that were not currently undertaken) of the waste processor, nothing had been changed in the prior marginal probability of the demolisher's workflow uncertainties (X_8), with this being admissible.

Table 7.15. Analysis of the effect of meso-level uncertainties of each of the demolisher and waste processor on QA in Case II

Observed variables	Focused variables	Prior marginal probability/ utility value	Without IPMs				With IPMs			
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C - With IPMs that were currently implemented		Scenario D – With all IPMs, including those that were not currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Meso-level uncertainties										
- Demolisher's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8756	0.9069	3.58%	0.8400	-4.06%	0.8681	-0.85%	0.8681	-0.85%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.8786	0.8797	0.13%	0.8772	-0.15%	0.8783	-0.03%	0.8783	-0.03%
	QA in RLSCs of DW	0.1120	0.0951	-15.13%	0.1313	17.18%	0.1160	3.60%	0.1160	3.60%
- Waste processor's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8756	0.8951	2.23%	0.6457	-26.25%	0.8756	0.00%	0.8756	0.00%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.8786	0.8967	2.06%	0.6658	-24.22%	0.8117	-7.61%	0.7566	-13.88%
	QA in RLSCs of DW	0.1120	0.0948	-15.37%	0.3144	180.69%	0.1376	22.82%	0.1586	41.62%

However, in Scenarios A and B, the percentages of change in the prior marginal probability of the demolisher's workflow uncertainties (X_8) indicated how much the prior marginal probability of X_8 needed to be changed to cause the 'mixed waste received from demolishers (X_{12})' to be either 'Yes' or 'No'.

When the demolisher's meso-level uncertainty had a 'Yes' status (i.e., in the worst-case scenario) and a 'No' status (i.e., in the best-case scenario), the utility value of QA decreased by 15.13% and increased by 17.18%, respectively. On the other hand, when the waste processor's meso-level uncertainty had a 'Yes' status (i.e., in the worst-case scenario) and a 'No' status (i.e., in the best-case scenario), the utility value of QA decreased by 15.37% and increased by 180.69%, respectively. These findings affirmed that, rather than the worst-case Scenario A, the utility value of QA could increase in larger percentages when meso-level uncertainties had a 'No' status (i.e., the best-case Scenario B). Furthermore, it was also apparent that the increment of the utility value of QA due to the absence of the waste processor's meso-level uncertainty was much higher than the increment caused by that of the demolisher. This finding emphasised the importance of addressing the 'mixed waste received from demolishers (X_{12})', one of the most sensitive uncertainties to enhancing the utility value of QA in Case II, as explained in Subsection 7.4.1.1. When considering Scenario C, that is, after implementing the current IPMs by the demolisher and waste processor in response to their meso-level uncertainties, the utility value of QA was increased by 3.60% and 22.82%, respectively. Let us suppose that the waste processor had implemented all the IPMs, including those not currently undertaken. In that case, the waste processor could have increased the utility value by 41.62% which was 18.80% more than the increment created by implementing the current IPMs. However, compared to the results for Scenario B, both the demolisher and waste processor must undertake IPMs more effectively in such a way that this yield results at the best-case level.

7.4.1.4.3 Analysis of the effect of micro-level uncertainties of each of the demolisher and waste processor on QA in RLSCs of DW

Table 7.16 shows the effect of micro-level uncertainties (observed variables) on workflow uncertainties of each of the demolisher and waste processor and the utility value of QA (focused variables) in Case II. According to Table 7.16, in the worst-case Scenario A, that is, when the micro-level uncertainties of each of the demolisher and waste processor had a 'Yes' status, the prior marginal probabilities of their

corresponding workflow uncertainties increased by 6.21% and 6.24%, respectively. On the other hand, in the best-case Scenario B, that is, when the micro-level uncertainties of each of the demolisher and waste processor had a 'No' status, the prior marginal probabilities of their corresponding workflow uncertainties reduced by 25.84% and 28.57%, respectively. Even if the increments in prior marginal probabilities of workflow uncertainties were nearly the same for each of the demolisher and waste processor in Scenario A, the reductions in these probabilities were higher for the waste processor than the demolisher in Scenario B. In Scenario C, that is, after implementing the current IPMs in response to micro-level uncertainties, the prior marginal probabilities of the demolisher's and waste processor's workflow uncertainties (i.e., X_8 and X_{16}) reduced by 9.27% and 4.24%, respectively.

When comparing the findings in Scenario C with those of Scenario B, the demolisher and waste processor could reduce workflow uncertainties more than they currently did by undertaking IPMs effectively in response to their micro-level uncertainties. In Case II, even if the demolisher was undertaking all the IPMs in response to its micro-level uncertainties, the waste processor was not undertaking 'creation of special reports (IPM_{10})' which could be implemented, especially in responding to 'product description complexities (X_{13})'. Given this result, the waste processor could have reduced the prior marginal probability of the waste processor's workflow uncertainties (X_{16}) by 11.02% if all the IPMs were implemented in response to its micro-level uncertainties, including the 'creation of special reports (IPM_{10})' (see Scenario D).

As shown in Table 7.16, when the demolisher's micro-level uncertainties had a 'Yes' status (i.e., in Scenario A), the prior marginal probability of the waste processor's workflow uncertainties increased by 0.23%. On the other hand, in Scenario B, that is, when the demolisher's micro-level uncertainties had a 'No' status, the prior marginal probability of the waste processor's workflow uncertainties decreased by 0.96%. Given these results, it was evident that the presence and absence of micro-level uncertainties of the demolisher were a reason for increasing and decreasing workflow uncertainties of the waste processor (X_8). Correspondingly, after implementing the current IPMs in response to micro-level uncertainties (i.e., in Scenario C), the prior marginal probabilities of the waste processor's workflow uncertainties were reduced by 0.35%.

Table 7.16. Analysis of the effect of micro-level uncertainties of each of the demolisher and waste processor on QA in Case II

Observed variables	Focused variables	Prior marginal probability/ utility value	Without IPMs				With IPMs			
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C – With IPMs that were currently implemented		Scenario D –-With all IPMs, including those that were not currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Micro-level uncertainties (except workflow uncertainties)										
- Demolisher's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8756	0.9299	6.21%	0.6493	-25.84%	0.7944	-9.27%	0.7944	-9.27%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.8786	0.8806	0.23%	0.8701	-0.96%	0.8755	-0.35%	0.8755	-0.35%
	QA in RLSCs of DW	0.1120	0.0826	-26.25%	0.2344	109.30%	0.1559	39.20%	0.1559	39.20%
- Waste processor's	Workflow uncertainties of the demolisher (X_8=Yes)	0.8756	0.8761	0.07%	0.8744	-0.14%	0.8756	0.00%	0.8756	0.00%
	Workflow uncertainties of the waste processor (X_{16}=Yes)	0.8786	0.9334	6.24%	0.6276	-28.57%	0.8414	-4.24%	0.7817	-11.02%
	QA in RLSCs of DW	0.1120	0.0908	-18.98%	0.2086	86.22%	0.1262	12.70%	0.1490	33.05%

In Scenario D, the prior marginal probability of the waste processor's workflow uncertainties increased by the same percentage (i.e., 0.35%) as the demolisher undertook all the IPMs in response to its micro-level uncertainties.

When the waste processor's micro-level uncertainties had a 'Yes' status (i.e., in Scenario A) and a 'No' status (i.e., in Scenario B), the prior marginal probability of the demolisher's workflow uncertainties increased and decreased by 0.07% and 0.14%, respectively. However, no change was found in the prior marginal probability of the demolisher's workflow uncertainties after implementing the current IPMs or all the IPMs in response to the waste processor's micro-level uncertainties (i.e., Scenarios C and D). According to the BBN-based conceptual information processing model in Figure 7.4, the demolisher's workflow uncertainties were not influenced by any of the waste processor's micro-level uncertainties. Therefore, after implementing either current IPMs or all the IPMs (including those not currently undertaken) in response to the waste processor's micro-level uncertainties, no change was admissible for observation in the prior marginal probability of the demolisher's workflow uncertainties (X_8). However, the percentage of changes in Scenarios A and B indicated how much the prior marginal probability of the demolisher's workflow uncertainties needed to increase or decrease to cause the waste processor's micro-level uncertainties to be either 'Yes' or 'No'.

Table 7.16 also shows that when the demolisher's micro-level uncertainties had a 'Yes' status (i.e., in the worst-case Scenario A), the utility value of QA decreased by 26.25%, and when it had a 'No' status (i.e., in the best case Scenario B), the utility value increased by 109.30%. On the other hand, when the waste processor's micro-level uncertainties had a 'Yes' status (i.e., in the worst-case Scenario A), the utility value of QA decreased by 18.98% and when it had a 'No' status (i.e., in the best-case Scenario B), the utility value increased by 86.22%. These findings affirmed that rather than reductions in the worst-case Scenario A, the utility value of QA could increase in large percentages in the best-case scenario when micro-level uncertainties had a 'No' status. In Scenario C, after current IPMs were implemented in response to micro-level uncertainties of each of the demolisher and waste processor, the utility value of QA increased by 39.20% and 12.70%, respectively. The increment in the utility value of QA due to the demolisher's IPMs was more than the increment caused by the waste processor's IPMs. These findings emphasised that minimising the demolisher's micro-

level uncertainties would greatly advocate an increased utility value of QA in Case II. Let us suppose that the waste processor had implemented all the IPMs, including those not currently undertaken. In that case, the utility value could have been increased by 33.05% which was 20.35% more than the increment created by the current IPMs. However, compared with results in the best-case Scenario B, both parties, especially the demolisher, had the opportunity to increase QA by undertaking IPMs more effectively than was currently the case.

7.4.1.4.4 Analysis of the effect of macro-, meso- and micro-level uncertainties on QA in RLSCs of DW

Table 7.17 shows the effect of the demolisher's and waste processor's epistemic uncertainties, including all macro-, meso- and micro-level uncertainties (observed variables) on the utility value of QA in Case II (focused variable). In the worst-case Scenario A, that is, when epistemic uncertainties in each category had a 'Yes' status, the largest reduction in the utility value of QA was due to macro-level uncertainties (45.86%), followed by micro- (45.09%) and then meso-level (27.98%) uncertainties. Both macro- and micro-level uncertainties reduced the utility value of QA by nearly the same percentage. On the other hand, in the best-case Scenario B, that is, when epistemic uncertainties in each category had a 'No' status, meso-level uncertainties increased the utility value of QA by a greater percentage (213.34%) than the increments created by macro- and micro-level uncertainties. The increment due to micro-level uncertainties (198.09%) was more than the increment arising from macro-level uncertainties (181.49%).

Scenario C outlined the increment in the utility value of QA after implementing all the current IPMs for each category of macro-, meso- and micro-level uncertainties. Accordingly, the highest increment in the utility value of QA in Case II was found to be due to macro-level uncertainties (114.00%). Attempts of internal stakeholders in Case II to reduce macro-level uncertainties should be applauded as when macro-level uncertainties had a 'Yes' status, the utility value of QA reduced by a higher percentage than with the other two types of uncertainties. Even if the utility value of QA could be increased by 198.09% by addressing micro-level uncertainties (i.e., as in Scenario B), Case II only succeeded in increasing it by 52.00% by undertaking IPMs. Furthermore, by undertaking current IPMs in response to meso-level uncertainties, Case II increased the utility value of QA by 26.46% which was the lowest utility value increment in

Scenario C. This indicated that Case II had not made much attempt to minimise its meso-level uncertainties, even if the highest increment in the utility value of QA could have been achieved by addressing meso-level uncertainties as per Scenario B. This finding was admissible as the waste processor in Case II had only undertaken one of three IPMs in response to 'mixed waste received from demolishers (X_{12})', one of the epistemic uncertainties to which the utility value of QA was highly sensitive (see Subsection 7.4.1.1).

Case II had not undertaken all IPMs in the BBN-based conceptual model. Accordingly, as shown in Table 7.17, Case II could have increased its utility value by 114.56% if the demolisher and waste processor had undertaken 'business partnering (IPM_3)' as an IPM in response to their 'incentivising uncertainties'. 'Creation of special reports (IPM_{10})' was the only IPM that Case II was not undertaking in response to micro-level uncertainties. If the waste processor had undertaken this IPM, the utility value of QA in Case II could have been increased to 72.45% which was 20.45% more than the increment in Scenario C. When considering meso-level uncertainties, the waste processor in Case II was not currently undertaking 'forming contracts (IPM_9)' and 'creation of integrator roles (IPM_6)' in response to 'mixed waste received from demolishers (X_{12})'. If these IPMs were implemented, the utility value of QA in Case II could have been increased to 45.17% which was 18.71% more than the increment in Scenario C. With these findings, it became understandable that the demolisher and waste processor in Case II had the opportunity to increase the utility value of QA, especially through implementing IPMs that the waste processor was not currently undertaking in response to micro-level uncertainties and the meso-level uncertainty. However, when considering the increment percentages in Scenarios C and D, both the demolisher and waste processor in Case II should still search for more opportunities to increase QA by enhancing the effectiveness of how they were undertaking IPMs.

Table 7.17. Analysis of the effect of macro-, meso- and micro-level uncertainties on QA in Case II

Observed variables	Focused variable	Utility value	Without IPMs				With IPMs			
			Worst-case Scenario A (Status = Yes)		Best-case Scenario B (Status = No)		Scenario C – With IPMs that were currently implemented		Scenario D – With all IPMs, including those that were not currently implemented	
			Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference	Posterior marginal probability/ utility value	Difference
Macro-level uncertainties	QA in RLSCs of DW	0.1120	0.0606	-45.86%	0.3153	181.49%	0.2397	114.00%	0.2403	114.56%
Meso-level uncertainties			0.0807	-27.98%	0.3510	213.34%	0.1416	26.46%	0.1626	45.17%
Micro-level uncertainties			0.0615	-45.09%	0.3339	198.09%	0.1703	52.00%	0.1932	72.45%

7.5 Cross-Case Analysis

This section presents the cross-case analysis of the multiple-case evidence. The significant epistemic uncertainties, depending on the probability of their occurrence and their effect on the utility value of QA, are first identified considering the findings of both cases. Next, the critical path of epistemic uncertainties is identified. After that, the significance of macro-, meso- and micro-level epistemic uncertainties for QA is explained followed by discussion of the significance of each IPM for QA in RLSCs of DW. Finally, a summary of the cross-case analysis results is presented.

7.5.1 Significant epistemic uncertainties depend on probability of their occurrence

Table 7.18 presents the cross-case analysis of epistemic uncertainties depending on their probability of occurrence and their effect on the utility value of QA across scenarios with and without implementation of IPMs. Accordingly, when none of the IPMs were implemented, Case I and II experienced 0.2095 and 0.1120 satisfaction with the utility value of QA, respectively. After implementing all the current IPMs, Case I increased its utility value of QA from 0.2095 to 0.6396, a significant increment compared to the results in Case II. Unlike Case I, as Case II was not undertaking all the IPMs in the BBN-based conceptual model, they were only able to increase their utility value of QA from 0.1120 to 0.3331. Even if all the IPMs were implemented, Case II could still increase the utility value of QA only up to 0.3827 which was a relatively low value compared to Case I. Considering all these results, it became evident that the utility values of QA in Case II, an RLSC with small and medium-scale organisations, were comparatively lower than those of Case I, an RLSC with large-scale organisations. It was apparent from Table 7.18 that the prior marginal probabilities of most epistemic uncertainties in Case II were always higher than those of Case I, except for 'management of demolisher's sub-contractors (X_4)'; ''as-is' condition of the building (X_5)'; and 'health and safety concerns of the demolisher (X_7)'. Even if Case II undertook all the IPMs, the prior marginal probabilities of epistemic uncertainties could not be reduced more than those in Case I.

As shown in Table 7.18, when none of the IPMs were undertaken in both cases, 'mixed waste received from demolishers (X_{12})' was the epistemic uncertainty with the highest prior marginal probabilities. This meant that, irrespective of the size of the waste

processing organisation, the likelihood was extremely high of receiving mixed waste from demolishers, adversely affecting the QA of the entire RLSC. Still, the small and medium-scale waste processor (WP2) in Case II had a higher likelihood of experiencing 'mixed waste received from demolishers (X_{12})' (i.e., 0.9216) than the large-scale waste processor (WP1) in Case I (i.e., 0.8234), when none of the IPMs were imposed against it. In Case I, without implementing any IPMs, 'workflow uncertainties of the demolisher (X_8)' and 'health and safety concerns of the demolisher (X_7)' had the second (i.e., 0.8057) and third (i.e., 0.8030) highest prior marginal probabilities, respectively. On the other hand, in Case II, 'workflow uncertainties of the waste processor (X_{16})' and 'workflow uncertainties of the demolisher (X_8)' had the second (i.e., 0.8786) and third (i.e., 0.8756) highest probabilities of occurrence, respectively. In Case I, most of the demolisher's epistemic uncertainties had higher prior marginal probabilities of occurrence (without implementing any of the IPMs) than those of the waste processor. However, as with meso-level uncertainties, some exceptions could be found. In contrast, in Case II, most of the waste processor's epistemic uncertainties had higher prior marginal probabilities of occurrence than those of the demolisher, still with some exceptions (e.g., demolisher's macro-level uncertainties including regulatory and incentivising uncertainties).

As mentioned in Sections 7.3 and 7.4, while Case I was undertaking all IPMs in the BBN-based conceptual model, Case II was not undertaking five of them. As discussed in Subsection 7.3.1.3.2 (also see Table 7.18), after implementing all the current IPMs, the prior marginal probabilities of epistemic uncertainties in Case I were reduced by more than 50%. However, in Case II, of all epistemic uncertainties, the prior marginal probabilities of only seven epistemic uncertainties were reduced by more than 50% after implementing their current IPMs (see Subsection 7.4.1.3.2 and Table 7.18). Still, after implementing all IPMs, including those not currently undertaken, Case II could reduce the prior marginal probabilities by more than 50% of only 10 epistemic uncertainties. This indicated that RLSCs with large-scale organisations succeeded more in reducing the probabilities of occurrence of epistemic uncertainties by undertaking effective IPMs than RLSCs with small and medium-scale organisations. In both cases, the ''as-is' condition of the building (X_5)' was the epistemic uncertainty with the highest reduction of prior marginal probabilities after implementing all current IPMs.

Table 7.18. Cross-case analysis of epistemic uncertainties depending on probability of their occurrence

Phase in RLSC		Epistemic uncertainty	Status	Case I (RLSC with large-scale demolition [D1] and waste processing [WP1] organisations)			Case II (RLSC with small and medium scale demolition [D2] and waste processing [WP2] organisations)				
				Probability of occurrence			Probability of occurrence				
				Without IPMs	With IPMs that were currently implemented	Difference (%) [X]	Without IPMs	With IPMs that were currently implemented	Difference (%) [X]	With IPMs that were not currently implemented	Difference (%) [Y]
Building dismantling and on-site processing	X_1	Regulatory uncertainties of the demolisher	**Yes**	0.7400	0.1100	-85.14%	0.8256	0.3500	-57.61%	0.3500	-57.61%
	X_2	Incentivising uncertainties of the demolisher	**Yes**	0.5588	0.1249	-77.65%	0.8541	0.5925	-30.63%	0.4115	-51.82%
	X_3	Contractual uncertainties from FSC-upstream actors	**Yes**	0.7413	0.1308	-82.35%	0.8285	0.3023	-63.51%	0.2993	-63.87%
	X_4	Management of demolisher's sub-contractors	**Yes**	0.7019	0.1392	-80.17%	0.5317	0.1012	-80.97%	0.1010	-81.01%
	X_5	'As-is' condition of the building	**Yes**	0.7645	0.0957	-87.48%	0.7497	0.1228	-83.62%	0.1224	-83.67%
	X_6	Management of contaminated/hazardous substances	**Yes**	0.7775	0.1782	-77.08%	0.8710	0.2855	-67.21%	0.2855	-67.23%
	X_7	Health and safety concerns of the demolisher	**Yes**	0.8030	0.3835	-52.25%	0.7908	0.4662	-41.04%	0.4662	-41.05%
	X_8	Workflow uncertainties of the demolisher	**Yes**	0.8057	0.3954	-50.93%	0.8756	0.6303	-28.01%	0.6299	-28.06%
Off-site processing	X_9	Regulatory uncertainties of the waste processor	**Yes**	0.6600	0.1000	-84.85%	0.7895	0.3254	-58.78%	0.3254	-58.78%
	X_{10}	Incentivising uncertainties of the waste processor	**Yes**	0.4460	0.1140	-74.44%	0.7813	0.5253	-32.78%	0.4173	-46.59%
	X_{11}	Contractual uncertainties from FSC-downstream actors	**Yes**	0.6815	0.1625	-76.15%	0.8353	0.3282	-60.70%	0.3080	-63.13%
	X_{12}	Mixed waste received from demolishers	**Yes**	0.8234	0.1286	-84.38%	0.9216	0.5597	-39.27%	0.3244	-64.81%
	X_{13}	Product description complexities	**Yes**	0.6180	0.1630	-73.62%	0.8707	0.7238	-16.87%	0.4142	-52.43%
	X_{14}	Human errors	**Yes**	0.7357	0.2227	-69.72%	0.7995	0.5330	-33.33%	0.4208	-47.36%
	X_{15}	Health and safety concerns of the waste processor	**Yes**	0.7748	0.3156	-59.26%	0.8187	0.5405	-33.97%	0.4930	-39.79%
	X_{16}	Workflow uncertainties of the waste processor	**Yes**	0.7698	0.3019	-60.78%	0.8786	0.6381	-27.38%	0.5046	-42.57%
Expected utility value of QA				**0.2095**	**0.6396**		**0.1120**	**0.3331**		**0.3827**	

This meant that IPMs undertaken by RLSCs (irrespective of whether they involved large-scale or small and medium-scale organisations) were mostly effective in reducing the prior marginal probabilities of the ‘‘as-is’ condition of the building (X_5)’, a micro-level uncertainty in the building dismantling and on-site processing phase. After implementing all the current IPMs, ‘workflow uncertainties of the demolisher (X_8)’ had the highest prior marginal probability of occurrence in Case I, followed by health and safety concerns of the demolisher (X_7) and the waste processor (X_{15}). On the other hand, after implementing all the current IPMs, ‘product description complexities (X_{13})’ had the highest prior marginal probability of occurrence in Case II. Furthermore, Case I reduced the probability of occurrence of ‘mixed waste received from demolishers (X_{12})’ by 84.38% by implementing IPMs, with this having been the epistemic uncertainty in both cases with the highest prior marginal probabilities of occurrence. However, if Case II had undertaken all the IPMs (including those not currently undertaken), the prior marginal probability of ‘mixed waste received from demolishers (X_{12})’ could have been reduced by 64.81%. These findings indicated the importance of undertaking all IPMs in the BBN-based conceptual model for QA in any RLSC with large or small and medium-scale organisations.

Both cases, by undertaking IPMs, reduced the prior marginal probabilities of occurrence of their macro- and meso-level uncertainties more than their micro-level uncertainties. It was found that the prior marginal probabilities of most macro-level uncertainties that appeared as root causes in the BBN-based conceptual model reduced by higher percentages than those of micro-level uncertainties at the top of the model. However, these reduction percentages were relatively higher in Case I than in Case II. For instance, when regulatory uncertainties of both demolisher and waste processor, that is, root causes in the BBN-based conceptual model, were reduced by more than 80% in Case I, workflow uncertainties which appeared at the top of the model were reduced by not more than 61%. On the other hand, in Case II, when regulatory uncertainties of the demolisher and waste processor were reduced by 35.56% and 58.78%, respectively, their corresponding workflow uncertainties were not reduced by more than 30%. Even though Case II had undertaken all IPMs, including those not currently undertaken, they could not achieve a satisfactory output as was the result in Case I. With this finding, the effectiveness of IPMs undertaken by RLSCs with small and medium-scale demolishers and waste processors became doubtful.

In Case II, 'management of demolisher's sub-contractors (X_4)' was the epistemic uncertainty with the lowest probability of occurrence in all scenarios: before undertaking current IPMs, after undertaking current IPMs and after undertaking all the IPMs, including those that were not currently undertaken. In Case I, the incentivising uncertainties of the waste processor (X_{10}) and demolisher (X_2) had the lowest probabilities of occurrence when none of the IPMs were implemented. However, compared to Case I, Case II experienced higher probabilities of occurrence for incentivising uncertainties. This finding was also observed in other macro-level uncertainties. Therefore, even if both cases represented the same industry in the same setting, they experienced varying degrees of macro-level uncertainties that originated from the industry's external environment.

7.5.2 Significant epistemic uncertainties depend on QA sensitivity

In Subsections 7.3.1.1 and 7.4.1.1, sensitivity analyses were carried out for Case I and II with tornado graphs developed to identify the epistemic uncertainties that caused a significant impact on QA. Accordingly, QA was most sensitive to 'workflow uncertainties of the demolisher (X_8)' in Cases I and II. At the same time, 'workflow uncertainties of the waste processor (X_{16})' was the second-highest epistemic uncertainty to which QA was most sensitive in both cases. According to the BBN-based conceptual model's arrangement, workflow uncertainties of the demolisher and waste processor were the only epistemic uncertainties directly linked to the objective node of QA. Therefore, the high sensitivity of QA to workflow uncertainties was admissible. In addition, epistemic uncertainties, such as 'regulatory uncertainties of the demolisher (X_1)'; 'mixed waste received from demolishers (X_{12});' and 'contractual uncertainties from FSC-upstream actors (X_3)', were the subsequent epistemic uncertainties to which QA was the most sensitive in both Cases I and II. Notably, three of these top five uncertainties were the demolisher's epistemic uncertainties. These findings indicated that QA in RLSCs was most sensitive to epistemic uncertainties of demolishing organisations, irrespective of whether they were large scale or small and medium scale.

When comparing the findings of Case I and II, macro-level uncertainties were found to moderately influence QA in RLSCs of DW, with QA more sensitive to macro-level uncertainties of demolishers than to those of waste processors. Moreover, the meso-level uncertainty of waste processors (i.e., 'mixed waste received from demolishers

[X_{12}]') influenced QA more than the meso-level uncertainty of demolishers (i.e., 'management of demolisher's sub-contractors [X_4]'). While the waste processor's meso-level uncertainty appeared within the top three epistemic uncertainties in having most influence on QA, the demolisher's meso-level uncertainty was within the least three influencing uncertainties for QA in both cases. Apart from this, in both cases, the following micro-level uncertainties, 'human errors (X_{14})'; ''as-is' condition of the building (X_5)'; and 'health and safety concerns of the waste processor (X_{15})' appeared at the bottom of the tornado graphs indicating that they were least influential on QA in RLSCs of DW. Notably, the within-case analyses showed that the satisfaction of internal stakeholders with QA in the absence of epistemic uncertainties was higher than their dissatisfaction in the presence of epistemic uncertainties. In this regard, the findings of Cases I and II established that, if appropriate IPMs could be undertaken especially to reduce the probability of occurrence of highly influential epistemic uncertainties, a great improvement in QA could be experienced in RLSCs of DW.

7.5.3 Critical path of epistemic uncertainties for QA

As explained in Subsection 7.5.2, the QA in RLSCs was most sensitive to workflow uncertainties of the demolisher and waste processor. According to the BBN-based conceptual model, all epistemic uncertainties of each of the demolisher and waste processor had direct or indirect relationships with their corresponding workflow uncertainties. All the epistemic uncertainties were propagated through and compounded towards workflow uncertainties, directly linking with QA. Therefore, in the within-case analyses, the critical path of epistemic uncertainties that augmented workflow uncertainties was identified through root cause analysis, applying the concept of back-propagation.

When the 'workflow uncertainties of waste processor (X_{16})' had a 'Yes' status (i.e.,100% or 1.000), 'mixed waste received from demolishers (X_{12})' was the most likely cause to present in both Cases I and II. Therefore, 'mixed waste received from demolishers (X_{12})' was the cause that significantly increased 'workflow uncertainties of the waste processor (X_{16})'. Notably, it was found in both cases that 'workflow uncertainties of the demolisher (X_8)' was the significant root cause of 'mixed waste received from demolishers (X_{12})'. Furthermore, 'management of contaminated/ hazardous substances (X_6)' was the most likely cause of 'workflow uncertainties of the

demolisher (X_8)' in both Cases I and II. When 'management of contaminated/ hazardous substances (X_6)' had a 'Yes' status (i.e., 100% or 1.000), the most likely cause to present was the ''as-is' condition of the building (X_5)' in Case I and 'regulatory uncertainties of the demolisher (X_1)' in Case II. As 'regulatory uncertainties of the demolisher (X_1)' was the root cause for the demolisher's remaining epistemic uncertainties, it became the root cause of the critical path. Therefore, in Case II, the critical path of epistemic uncertainties concluded with 'regulatory uncertainties of the demolisher (X_1)'. In Case I, the most likely cause for ''as-is' condition of the building (X_5)' was 'contractual uncertainties from FSC-upstream actors (X_3)'. In Case II, when 'management of contaminated/hazardous substances (X_6)' had a 'Yes' status (i.e., 100% or 1.000), ''as-is' condition of the building (X_5)' had nearly the same likelihood of occurrence as 'regulatory uncertainties of the demolisher (X_1)'. Finally, 'regulatory uncertainties of the demolisher (X_1)' was the most likely cause for 'contractual uncertainties from FSC-upstream actors (X_3)' having a 'Yes' status (i.e., 100%). Considering the findings from both these contexts (i.e., Cases I and II), the critical path of epistemic uncertainties for QA in RLSCs of DW is shown in Figure 7.7. Accordingly, Figure 7.7 illustrates that workflow uncertainties of the waste processor are compounding mostly not as a result of the waste processor's macro- and micro-level uncertainties but from the demolisher's workflow uncertainties through receiving mixed waste from the demolisher.

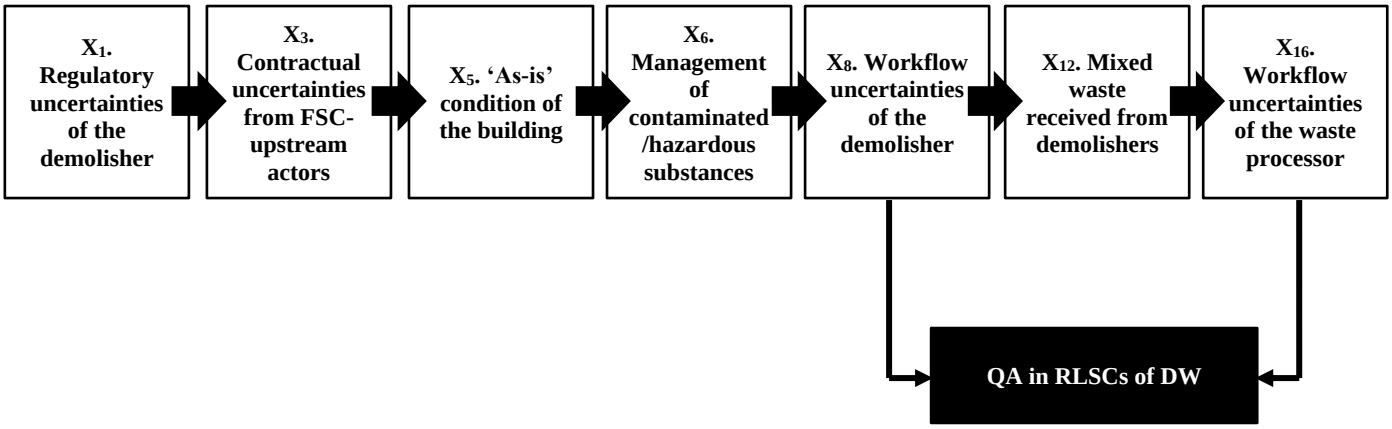


Figure 7.7. Critical path of epistemic uncertainties for QA in RLSCs of DW

7.5.4 Significance of macro-, meso- and micro-level epistemic uncertainties for QA in RLSCs of DW

Table 7.19 shows the cross-case analysis of changes in the utility value of QA according to different scenarios of macro-, meso- and micro-level uncertainties of the demolisher and waste processor. When considering all three classifications of epistemic uncertainties, irrespective of the demolisher or waste processor, QA was most sensitive to macro-level uncertainties in both cases, followed by micro- and meso-level uncertainties. Notably, the demolisher's epistemic uncertainties caused greater changes in the utility value of QA in both cases than the waste processor's epistemic uncertainties, except for meso-level uncertainties.

Table 7.19. Significance of macro-, meso- and micro-level epistemic uncertainties for QA

Observed variables	Change in the utility value of QA (%)						
	Case I (Utility value of QA = 0.2095)			Case II (Utility value of QA = 0.1120)			
	Without IPMs		With IPMs	Without IPMs		With IPMs	
	Scenario A – Worst-case (Status = Yes)	Scenario B – Best-case (Status = No)	Scenario C – With IPMs that were currently implemented	Scenario A – Worst-case (Status = Yes)	Scenario B – Best-case (Status = No)	Scenario C – With IPMs that were currently implemented	Scenario D – With all IPMs, including those that were not currently implemented
Macro-level uncertainties							
Demolisher's	-31.34%	82.41%	70.24%	-28.60%	115.19%	75.18%	75.40%
Waste processor's	-21.85%	42.90%	35.20%	-17.25%	66.58%	38.92%	39.25%
Meso-level uncertainties							
Demolisher's	-5.28%	12.43%	6.33%	-15.13%	17.18%	3.60%	3.60%
Waste processor's	-15.25%	71.07%	26.55%	-15.37%	180.69%	22.82%	41.62%
Micro-level uncertainties							
Demolisher's	-22.12%	73.38%	30.94%	-26.25%	109.30%	39.20%	39.20%
Waste processor's	-26.48%	52.18%	22.35%	-18.98%	86.22%	12.70%	33.05%

Among all epistemic uncertainties, the demolisher's macro-level uncertainties could make the highest deviations in the utility value of QA depending on changes in their status. For instance, as shown in Table 7.19, after implementing all the current IPMs in response to the demolisher's macro-level uncertainties, Case I and II had increased their corresponding utility values of QA by 70.24% and 75.18%, respectively. This emphasised that the demolishers had undertaken effective IPMs in response to their macro-level uncertainties in both cases. The utility values of QA had also substantially increased due to the IPMs undertaken in response to waste processors' macro-level

uncertainties. However, these increments are still nearly half of the increments created by IPMs of the demolishers against their macro-level uncertainties. In comparing the two cases, the RLSC with small and medium-scale organisations (i.e., Case II) increased the utility value of QA more than Case I with large-scale organisations, by appropriately responding to macro-level uncertainties. Case II could further increase the utility value of QA by undertaking 'business partnering (IPM_3)' as an IPM, especially in response to incentivising uncertainties of both the demolisher and waste processor. However, these approximately slight increments would be not more than 0.50% than the status quo.

Unlike the macro-level uncertainties, the RLSC with large-scale organisations (i.e., Case I) succeeded in increasing the utility value of QA by greater percentages than Case II, with the RLSC with small and medium-scale organisations, by appropriately responding to meso-level uncertainties. As shown in Table 7.19, QA in both cases was more sensitive to the waste processor's meso-level uncertainty than to that of the demolisher. The changes in status (i.e., 'Yes' or 'No') of the demolisher's meso-level uncertainty caused the lowest fluctuations in the utility value of QA among all epistemic uncertainties in both Cases I and II. Therefore, even after implementing all IPMs in response to the demolisher's meso-level uncertainty, the utility values of QA in both cases only slightly increased. In contrast, when the waste processor's meso-level uncertainty had a 'No' status, the utility values of QA increased significantly in both cases. However, it was found that after implementing IPMs in response to the waste processor's meso-level uncertainty, both cases experienced smaller increments in the utility values of QA compared to the increments in Scenario B. The increment in the utility value of QA in Case I was higher than the increment in Case II. Let us suppose that Case II had undertaken all IPMs, including those not currently undertaken, in response to the waste processor's meso-level uncertainty. If so, Case II could have approximately doubled the current increment in the utility value of QA which would be even more than the increment in Case I. Therefore, both cases should still consider ways to improve the effectiveness of their current IPMs implemented against the demolisher's and waste processor's meso-level uncertainties to yield an output such as that achieved in Scenario B.

When considering micro-level uncertainties, in the best-case Scenario B, the increments in the utility values of QA were higher in Case II than in Case I. Correspondingly, from

the demolisher's perspective, after implementing IPMs in response to micro-level uncertainties, the utility value of QA increased by a higher percentage in Case II than in Case I. However, from the waste processor's perspective, after implementing IPMs in response to its micro-level uncertainties, a higher increment in the utility value of QA was observed in Case I than in Case II. As the waste processor in Case II had not undertaken 'creation of special reports (IPM_{10})', an IPM that could be specifically undertaken in response to 'product description complexities (X_{13})', the lower increment in the utility value of QA in Case II was admissible. Therefore, Case II could increase the utility value of QA by more than twice the current increment if the waste processor in Case II undertook all the IPMs, including 'creation of special reports (IPM_{10})'.

7.5.5 Significance of each IPM for QA in RLSCs of DW

Table 7.20 illustrates the cross-case analysis of the significance of IPMs for both the demolisher and the waste processor on increments in the utility value of QA. Unlike Case I, Case II had not undertaken five IPMs in the BBN-based conceptual model (see Section 7.4). Table 7.20 shows the increments of the utility value of QA that could be achieved in Case II if these IPMs were implemented.

As shown in Table 7.20, the highest increments in the utility value of QA were due to 'rules and programs (IPM_1)' in both Case I and Case II. 'Rules and programs (IPM_1)' of the demolisher were found to be more effective in increasing the utility value of QA than that of the waste processor in both cases. From the demolisher's perspective, the second-highest increments in the utility value of QA were due to 'planning and goal setting (IPM_2)' in both cases. However, the waste processor had not succeeded in increasing the utility value of QA as the demolisher had via 'planning and goal setting (IPM_2)' in both cases. Consequently, 'waste acceptance criteria/gate fees (IPM_8)' was the IPM in both cases that led to the second-highest increments in the utility value of QA from the waste processor's perspective.

Table 7.20. Significance of each IPM for QA in RLSCs of DW

Phase in RLSC	Epistemic uncertainties and corresponding IPMs	Change in the utility value of QA (%)		
		Case I (utility value = 0.2095)	Case II (utility value = 0.1120)	
		With IPM(s) that were currently implemented	With IPM(s) that were currently implemented	With IPM(s) that were not currently implemented
Building dismantling and on-site processing	**X_1. Regulatory uncertainties of the demolisher**			
	Rules and programs	59.90%	53.79%	-
	X_2. Incentivising uncertainties of the demolisher			
	Business partnering	0.32%	-	0.71%
	X_3. Contractual uncertainties from FSC-upstream actors			
	Planning and goal setting	17.20%	31.79%	-
	X_4. Incorporation of many sub-contractors			
	Forming contracts	2.54%	1.31%	-
	Performance evaluation of sub-contractors	1.67%	0.78%	-
	Group meetings	0.83%	0.29%	-
	All IPCs	6.33%	3.60%	-
	X_5. 'As-is' condition of the building			
	Collection of as-built drawings/asbestos registers	3.23%	1.96%	-
	Site visits/pre-demolition audits	2.89%	1.74%	-
	Hierarchical referral	0.41%	0.09%	-
	All IPCs	7.71%	5.14%	-
	X_6. Management of contaminated/hazardous substances			
	Investment in technologies	0.62%	2.40%	-
	Incorporation of self-contained groups	8.83%	6.10%	-
	All IPCs	16.56%	11.55%	-
	X_7. Health and safety concerns of the demolisher			
	Creation of slack resources	4.68%	19.60%	-
Off-site waste processing	**X_9. Regulatory uncertainties of the waste processor**			
	Rules and programs	32.52%	36.60%	-
	X_{10}. Incentivising uncertainties of the waste processor			
	Business partnering	0.06%	-	0.17%
	X_{11}. Contractual uncertainties from FSC-downstream actors			
	Planning and goal setting	5.70%	2.78%	-
	X_{12}. Mixed waste from demolishers			
	Waste acceptance criteria/gate fees	13.00%	22.82%	-
	Forming contracts	7.41%	-	8.30%
	Creation of integrator roles	6.14%	-	6.60%
	All IPCs	26.55%	22.82%	41.62%
	X_{13}. Product description complexities			
	Creation of special reports	10.24%	-	19.12%
	Group meetings	2.55%	5.79%	-
	All IPCs	14.86%	5.79%	25.69%
	X_{14}. Human errors			
	Investment in technologies	0.63%	1.09%	-
	Hierarchical referral	0.38%	0.67%	-
	Incorporation of self-contained groups	1.67%	2.92%	-

Phase in RLSC	Epistemic uncertainties and corresponding IPMs	Change in the utility value of QA (%)		
		Case I (utility value = 0.2095)	Case II (utility value = 0.1120)	
		With IPM(s) that were currently implemented	With IPM(s) that were currently implemented	With IPM(s) that were not currently implemented
	All IPCs	4.82%	5.42%	-
	X_{15}. Health and safety concerns			
	Creation of slack resources	1.22%	1.17%	-

As shown in Table 7.20, the increments in the utility value of QA due to the separate or combined implementation of demolishers' IPMs were higher in Case I than in Case II. From the demolisher's perspective, only a few IPMs in both cases, such as 'rules and programs (IPM_1)'; 'planning and goal setting (IPM_3)'; and 'incorporation of self-contained groups (IPM_{14})', caused the utility value of QA to increase by more than 5%. In Case II, 'creation of slack resources (IPM_{15})' undertaken in response to 'health and safety concerns of the demolisher (IPM_7)' increased the utility value of QA by 19.60%. However, in Case I, it only caused a 4.68% increment. This result emphasised that even if 'creation of slack resources (IPM_{15})' was the last resort IPM undertaken in response to propagated epistemic uncertainties in a situation, such as 'health and safety concerns', it would still increase QA significantly, especially in the context of small and medium-scale demolishers. Except for the following IPMs of the demolisher, all remaining epistemic uncertainties caused less than 5% increments in the utility value of QA in both cases. The lowest increments in the utility value of QA were found in both cases to be due to the demolisher's IPMs, such as 'business partnering (IPM_3)', 'group meetings (IPM_{12})' and 'hierarchical referral (IPM_{13})'. Even if Case II had undertaken 'business partnering', the utility value of QA could only be increased by 0.71%. However, if implemented in combination, most IPMs led to better increments in the utility value of QA. For instance, by implementing 'investment in technologies (IPM_{11})' and 'incorporation of self-contained groups (IPM_{14})' in combination in response to 'management of contaminated/hazardous substances (X_6)', the utility value of QA increased by higher percentages in both cases than the increments created by each of these IPMs if implemented separately.

Increments in the utility value of QA due to separate or combined implementation of the waste processor's IPMs were higher in Case II than in Case I. In contrast to the demolisher's IPMs, most of the IPMs of the waste processor increased the utility value of QA by more than 5%, even if they were implemented separately. From the waste

processor's perspective, the highest increments in the utility value of QA in both cases were due to the implementation of 'rules and programs (IPM_1)' and 'waste acceptance criteria/gate fees (IPM_8)'. In addition, the next highest increment in the utility value of QA was due to the implementation of 'creation of special reports (IPM_{10})' which was an IPM currently undertaken by Case I, but not by Case II. The lowest increments in the utility value of QA (due to the waste processor's IPMs) could be found in both cases due to 'business partnering (IPM_3)'; 'hierarchical referral (IPM_{13})'; and 'investment in technologies (IPM_{11})'. Even if Case II had undertaken 'business partnering', the utility value of QA could only be increased by 0.17%. As in the demolisher's perspective, from the waste processor's perspective, it was found that whenever more than one IPM was present in response to an epistemic uncertainty, if they were implemented in combination, higher increments in the utility value of QA could be expected.

7.5.6 Summary of results of the cross-case analysis

In this study, two cases were selected to predict contrasting results in accordance with the concept of theoretical replication of the case study (Yin 2009). Accordingly, Case I was an RLSC consisting of a large-scale demolisher and waste processor, while the RLSC in Case II comprised a small and medium-scale demolisher and waste processor. When scrutinising the cross-case analysis findings, both contrasting and similar results were identified across the two cases regarding epistemic uncertainty propagation in RLSCs of DW, with these findings worth summarising, as shown in Table 7.21.

Table 7.21 shows a few contrasting results between Case I and Case II depending on the criteria, utility values of QA and probability of occurrence. Accordingly, the utility values of QA were higher in Case I than in Case II before and after implementing IPMs. As explained in Subsection 7.5.1, the probability of occurrence of most epistemic uncertainties in Case II was high compared to that of Case I in both scenarios whether with or without IPMs. This indicated that RLSCs with small and medium-scale demolishers and waste processors were more vulnerable to most epistemic uncertainties than RLSCs with large-scale organisations. Even when this result was compared to Case I, it was admissible to observe low utility values of QA in all Case II scenarios. Without implementing any IPMs, most of the demolisher's' epistemic uncertainties had high probabilities of occurrence in Case I. In Case II, the highest probabilities were with most of the waste processor's epistemic uncertainties. Notably, 'mixed waste received

from demolishers (X_{12})' was the epistemic uncertainty with the highest probability of occurrence (without implementing IPMs) in both cases.

Table 7.21. Summary of results of the cross-case analysis

Criteria	Case I	Case II
Utility value of QA	**High**	**Low**
- Before implementing any IPMs	0.2095	0.1120
- After implementing IPMs	0.6396	0.3331
Probability of occurrence	**Comparatively Low**	**Comparatively High**
Before implementing IPMs		
- Epistemic uncertainty with the highest probability of occurrence	Mixed waste received from demolishers (X_{12})	
- Epistemic uncertainty with the lowest probability of occurrence	Incentivising uncertainties of the waste processor ($_{10}$)	Management of demolisher's sub-contractors (X_4)
After implementing IPMs		
- Highest reduction in the probability of occurrence	'As-is' condition of the building (X_5)	
- Epistemic uncertainties with the highest probability of occurrence	Workflow uncertainties of the demolisher (X_1)	Product description complexities (X_{13})
- Epistemic uncertainties with the lowest probability of occurrence	'As-is' condition of the building (X_5)	Management of demolisher's sub-contractors (X_4)
Sensitivity of QA		
- Most sensitive	Workflow uncertainties of the demolisher (X_8) Workflow uncertainties of the waste processor (X_{16}) Regulatory uncertainties of the demolisher (X_1) Mixed waste received from demolishers (X_{12}) Contractual uncertainties from FSC-upstream actors (X_3)	
- Least sensitive	Human errors (X_{14}) 'As-is' condition of the building (X_5) Health and safety concerns of the waste processor (X_{15})	
- Critical path of epistemic uncertainties	Regulatory uncertainties of the demolisher (X_1); Contractual uncertainties from the FSC-upstream actors (X_3); 'As-is' condition of the building (X_5); Management of contaminated/hazardous substances (X_6); Workflow uncertainties of the demolisher (X_8); Mixed waste received from demolishers (X_{12}); Workflow uncertainties of the waste processor (X_{16})	
- Most sensitive epistemic uncertainty classification	1. Macro-level uncertainties 2. Micro-level uncertainties 3. Meso-level uncertainties	
IPMs		
- Significant IPMs	Rules and programs of both demolisher and waste processor (IPM_1) Planning and goal setting of the demolisher (IPM_2) Waste acceptance criteria/gate fees (IPM_8)	
- Effectiveness of IPMs	Respond to meso-level uncertainties and waste processor's micro-level uncertainties	Respond to macro-level uncertainties and demolisher's micro-level uncertainties

In contrast, 'incentivising uncertainties of the waste processor (X_{10})' and 'management of demolisher's contractors (X_4)' were the epistemic uncertainties with the lowest

probabilities of occurrence (without implementing IPMs) in Case I and II, respectively. With the implementation of IPMs, the highest reduction in the probability of occurrence was found in the ‘‘as-is’ condition of the building (X_5)’ in both cases. This emphasised that IPMs were more effective in reducing uncertainties related to ‘‘as-is’ condition of building’ in RLSCs, irrespective of whether they comprised large-scale or small and medium-scale organisations. Consequently, ‘‘as-is’ condition of the building (X_5)’ had the lowest probability of occurrence in Case I after implementation of IPMs, and in Case II, the lowest probability was again with ‘management of demolisher’s sub-contractors (X_4)’. Even after implementing IPMs, ‘workflow uncertainties of the demolisher (X_8)’ and ‘product description complexities (X_{13})’ had the highest probabilities of occurrence in Case I and Case II, respectively.

As shown in Figure 7.8, many similar results were also identified between the two cases, especially when considering the impact of epistemic uncertainties on QA. Accordingly, as per the epistemic uncertainty classifications, QA was most influenced by macro-level uncertainties in both cases, followed by micro- and meso-level uncertainties. The demolisher’s macro-level uncertainties were also prominent. When considering the cross-case sensitivity analysis, the top five epistemic uncertainties to which QA was most sensitive were similar in both cases despite changes in their order of placement. Accordingly, QA in both cases was most sensitive to ‘workflow uncertainties of the demolisher (X_8)’; ‘workflow uncertainties of the waste processor (X_{16})’; ‘regulatory uncertainties of the demolisher (X_1)’; ‘mixed waste received from demolishers (X_{12})’; and ‘contractual uncertainties from FSC-upstream actors (X_3)’. Two of these most sensitive epistemic uncertainties were the demolisher’s macro-level uncertainties. Therefore, the significant impact of the demolisher’s macro-level uncertainties on QA in RLSCs was admissible.

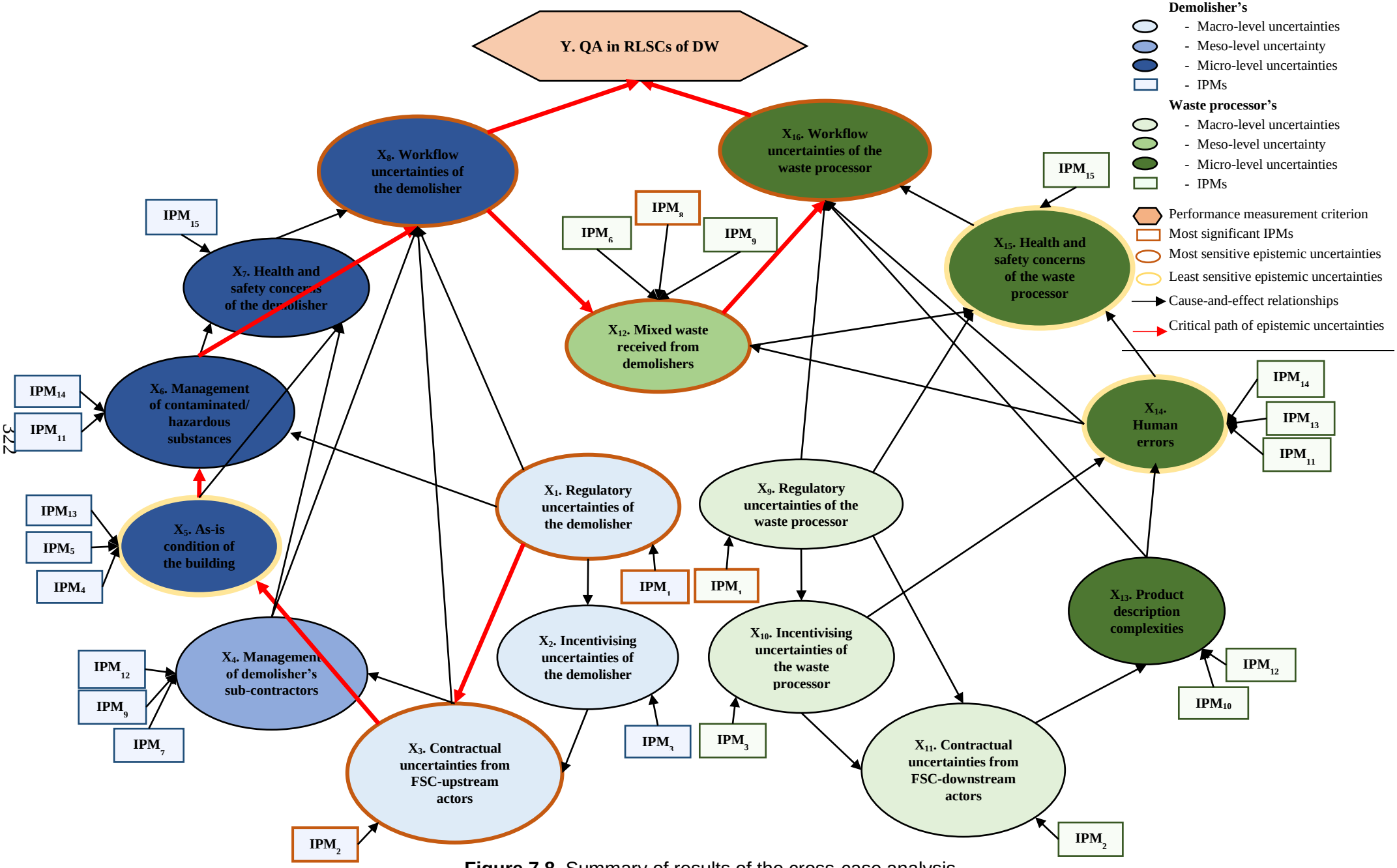


Figure 7.8. Summary of results of the cross-case analysis

The cross-case analysis also found that the critical path of epistemic uncertainties for QA was almost the same in both cases. Consequently, this critical path was sequentially arranged as 'workflow uncertainties of the waste processor (X_{16})'; 'mixed waste received from demolishers (X_{12})'; 'workflow uncertainties of the demolisher (X_8)'; 'management of contaminated/hazardous substances (X_6)'; ''as-is' condition of the building (X_5)'; 'contractual uncertainties from the FSC-upstream actors (X_3)'; and 'regulatory uncertainties of the demolisher (X_1)'. Notably, the least sensitive epistemic uncertainties for QA were also almost similar in both cases. The least sensitive epistemic uncertainties were 'human errors (X_{14})'; ''as-is' condition of the building (X_5)'; and 'health and safety concerns of the waste processor (X_{15})'.

The cross-case analysis also found that in Case I and Case II, 'rules and programs (IPM_1)' was the most effective IPM for the demolisher and waste processor to undertake in response to epistemic uncertainties. According to the BBN-based conceptual model, rules and programs appear as an IPM, especially in response to the regulatory uncertainties of the demolisher and waste processor. Consequently, reducing the probability of occurrence of regulatory uncertainties and thereby increasing the utility value of QA by greater percentages than would be the case with other IPMs was advocated in both cases. Apart from this, 'planning and goal setting (IPM_2)' of the demolisher and 'waste acceptance criteria/gate fees (IPM_8)' of the waste processor were two other effective IPMs that significantly reduced the probability of occurrence of their corresponding epistemic uncertainties, thus increasing the utility value of QA in RLSCs. The IPMs in Case I responded more effectively to meso-level uncertainties of both the demolisher and waste processor and to micro-level uncertainties only of the waste processor. On the other hand, the IPMs of Case II successfully responded to macro-level uncertainties of the demolisher and waste processor and the micro-level uncertainties of the demolisher. The reductions of probabilities and, thereby, increments in the utility value of QA due to IPMs were not found to be vastly different between Case I and Case II. This indicated that even if the utility value of QA was low, information processing was equally effective and sometimes even better in Case II than in Case I. This finding was admissible as Case II had effectively responded to macro-level uncertainties of the demolisher and waste processor which were root causes of the BBN-based conceptual model. Given this finding, it is worth mentioning that appropriately responding to root causes or sources of epistemic uncertainties was more important for enhancing information processing for QA in RLSCs of DW.

7.6 Concluding Remarks

This chapter discussed the applicability of the BBN-based conceptual information processing model for QA in the context of RLSCs of DW using two case studies. The first case study was an RLSC composed of a large-scale demolisher and waste processor, while the other case study was an RLSC comprising a small and medium-scale demolisher and waste processor. Both within-case and cross-case analyses were presented in this chapter, with these analyses examining the trends in epistemic uncertainty propagation in RLSCs of DW. The exhaustive analysis found that RLSCs with small and medium-scale demolishers and waste processors were more vulnerable to most epistemic uncertainties than RLSCs with large-scale organisations. The 'mixed waste received from demolishers(X_{12})' was the epistemic uncertainty with the highest probability of occurrence. After implementing the IPMs, ''as-is' condition of the building (X_5)' was the epistemic uncertainty with the highest reduction of probability of occurrence. The study also found that the utility value of QA in RLSCs was most sensitive to workflow uncertainties of the demolisher (X_8) and waste processor (X_{16}). On the other hand, the least sensitive uncertainties for QA were 'human errors (X_{14})'; ''as-is' condition of the building (X_5)'; and 'health and safety concerns of the waste processor (X_{15})'. The critical path of epistemic uncertainties for QA was the same in any RLSC irrespective of whether it includes large-scale or small and medium-scale organizations. It was sequentially arranged as 'workflow uncertainties of the waste processor (X_{16})'; 'mixed waste received from demolishers (X_{12})'; 'workflow uncertainties of the demolisher (X_8)'; 'management of contaminated/hazardous substances (X_6)'; ''as-is' condition of the building (X_5)'; 'contractual uncertainties from the FSC-upstream actors (X_3)'; and 'regulatory uncertainties of the demolisher (X_1)'. Furthermore, macro-level uncertainties of both the demolisher and waste processor, which appeared as root causes of the BBN-based conceptual information processing model, were the most influential category of epistemic uncertainties on the utility value of QA in RLSCs of DW. Therefore, IPMs, such as 'rules and programs (IPM_1)' and 'planning and goal setting (IPM_2)' that respond to macro-level uncertainties, such as regulatory and contractual uncertainties, were more effective in enhancing QA in RLSCs of DW than other IPMs. In light of this, the study posits that responding to root cause-level epistemic uncertainties was more significant for enhancing information processing for QA in RLSCs of DW. The next chapter discusses the collective research findings from the semi-structured interviews (Chapter 4), the structured interviews (Chapter 5), the focus group discussion (Chapter 6) and the case studies (Chapter 7).

8 Discussion

8.1 Introduction

This chapter discusses the empirical findings outlined in Chapter 4 (from the semi-structured interviews), Chapter 5 (from the structured interviews), Chapter 6 (from the focus group discussion) and Chapter 7 (from the case studies). These findings are critically reviewed from theoretical and practical perspectives and compared with the literature. The chapter is organised as follows. First, it discusses key findings related to aspects of the QAS in RLSCs of DW. The epistemic uncertainties and IPMs for QA in RLSCs of DW are then discussed. Lastly, based on these key findings, the relationship between aspects of the QAS, epistemic uncertainties and IPMs is established and discussed in detail.

8.2 Aspects of QAS in RLSCs of DW

Previous studies highlighted that, irrespective of the industry, QA is not a solitary effort (Fox 2013; Wijewickrama et al. 2021a). Fox (2013) asserted that in the manufacturing industry, four aspects contribute to QA: (i) the item being worked upon; (ii) the documentation required; (iii) the equipment being used; and (iv) the person carrying out the job. Based on this assertion, Wijewickrama et al. (2021a), through a systematic literature review (SLR), conceptualised that an integrated system of process, people, policy and technology is vital for QA in RLSCs of DW. These authors highlighted the need for further studies to empirically establish how the aspects of process, people, policy and technology contribute to QA in RLSCs of DW. Thus, the first objective of this study was to progress toward bridging this gap in the literature, with this achieved through conducting 30 semi-structured interviews (see Chapter 3, Subsection 3.5.1.1). The findings of these semi-structured interviews, outlined in Chapter 4 (see Section 4.4), are discussed in the following subsections.

8.2.1 Process for QA

'Process' is the first aspect of the integrated system for QA in RLSCs of DW. Jacobs (2019) explained a process as a set of interrelated human actions and technology-based events undertaken across functional boundaries involving diverse groups of people, with the purpose of converting the inputs into outputs. According to Summers (2019), in a QAS, the expected level of product quality should be maintained by considering the QA practices in each phase of the production process. Thus , the current study's findings established QA practices during the two phases of RLSCs of DW: building dismantling and on-site processing and off-site waste processing. Accordingly, the process for QA in RLSCs of DW should be initiated by becoming familiar with the job. To achieve this, the demolisher could visit the site and thoroughly investigate the status quo of the building by referring to the drawings and asbestos registers. Corresponding with Zoraja et al. (2021) and Zoraja et al. (2022), the current study affirmed that asbestos management is a crucial QA practice that needs to be undertaken during the building dismantling and on-site processing phase. The decision to deconstruct instead of demolishing everything at once is also of paramount importance to be undertaken during this phase. However, as previous studies stated, even in SA, demolishers are still willing to pursue demolition instead of deconstruction as demolition consumes more time and money and is labour intensive (Akinade et al. 2017; Anastasiades et al. 2022). For these reasons, demolishers in SA often follow a systematic and sequential dismantling process guided through the extant regulations: starting from removing asbestos, soft stripping and then mechanical demolition. This approach complies with the concept of selective demolition which means 'the removal of materials from a demolition site in a pre-defined sequence before demolition or renovation, in order to maximise recovery and recycling performance' (Wu, PY et al. 2021, p. 4). However, the study found that demolishers have no guiding benchmark to decide the degree to which deconstruction and demolition should, respectively, be undertaken to optimise the maximum benefits from the perspectives of materials recovery, time and cost. As a solution, Ge et al. (2017) stated that identifying materials, based on 'can be reprocessed' and 'cannot be reprocessed', before dismantling would be an ideal approach for deciding the point at which to optimise deconstruction and demolition methods to yield maximum benefits. Even if an optimised level of deconstruction is performed, cross-contamination of waste hinders the recovery of significant volumes of salvageable waste for reprocessing (Ge et al. 2017; Wang, Z, Li & Yang 2020). Therefore, congruent with previous studies (Ratnasabapathy, Alashwal & Perera 2021; Wang, Z, Li & Yang 2020), the current

study found that on-site sorting is a significant QA practice which avoids piles of contaminated waste after dismantling. Furthermore, appropriate storage, handling and transportation are crucial to avoid cross-contamination and damage to salvageable waste from unfavourable weather conditions. Trochu, Chaabane and Ouhimmou (2018) mentioned that transporting salvageable waste to a reprocessing facility closer to the demolition site assisted in minimising contamination during transportation. However, this is not always practicable when considering contexts, such as SA, where all the MRFs are located far from metropolitan areas. In addition to these practices, the current study found that continuous risk assessment throughout the dismantling job is vital to enhance the quality of the process while ensuring no damage or harm to humans, adjacent buildings, plants and equipment. Demolishers only follow QA during their process when a legal imposition exists; if not, they find illegal dumping of mixed waste after demolition is a more convenient, inexpensive and quicker option (Brandão et al. 2021a; Trochu, Chaabane & Ouhimmou 2018; Wijewickrama et al. 2022). Previous studies revealed that the combined use of landfill disposal fees, penalties and fines, and government subsidies are effective in triggering demolishers to undertake the above QA practices and hand over the maximum amount of sorted salvageable waste to MRFs for reprocessing (Brandão et al. 2021b; Jia et al. 2017). However, it was found through the current study that even if landfill disposal fees and penalties and fines are enacted, minimal availability of government subsidies in SA for demolishers is a serious issue for QA in RLSCs of DW.

Chileshe, Jayasinghe and Rameezdeen (2019) mentioned that the process quality of the waste processor primarily depended on the quality of waste that enters the MRF. Correspondingly, the current study revealed that minimising the possibility of receiving mixed waste from demolishers is a make-or-break practice of waste processors, from which the QA process is also initiated during the off-site waste processing phase. As RLSCs of DW constitute interrelated operational phases, Ratnasabapathy, Alashwal and Perera (2021) stated that if QA practices in the demolition phase were well performed, more materials could be recovered while avoiding mixed waste being received by MRFs. Thus, many quality issues during waste processing could be eradicated. When a waste load is transferred into the MRF, the waste processor should conduct an exhaustive examination at the weighbridge to ensure that the waste is not contaminated. Waste processors in SA have been assigned two roles: ‘customer service representative’ and ‘spotter’ for the initial inspection at the weighbridge, in addition to the surveillance of waste loads through CCTV cameras. The exhaustive process of

off-site sorting before introducing salvageable waste to the processing plant is also a significant step in the process for QA during the off-site waste processing phase. As in developing countries like Hong Kong (Lu & Yuan 2012; Poon, Yu & Ng 2001) and Taiwan (Huang, WL et al. 2002), in SA too, which is a developed context, the general off-site waste sorting process consists of varied steps such as trommel screening, flip-flop screening, air classification, manual picking, magnetic screening and overbuilt blowing. The current study found that thorough QC at the end of the process is also an important practice for QA during the off-site waste processing phase. Even if the terms QA and QC have been used in tandem and interchangeably, Delis et al. (2017) indicated that QC is one aspect of QA, with QC being the final assessment of the products to assure that they meet the relevant quality standards. In SA, the quality of reprocessed products is checked for density, versatility, durability and sustainability against the DIT sampling specifications. Previous studies suggested that if a product certification is awarded following QC, the adoption of reprocessed products could be enhanced in the construction industry (Chileshe et al. 2016; Shooshtarian et al. 2020). Shooshtarian et al. (2020) raised the need for a government agency to assess the waste processors' QC process of reprocessed products. However, despite greater attempts to promote reprocessed products, none of these strategies have been adopted in the DW management industry in SA.

8.2.2 People for QA

'People' is the second aspect of the integrated system for QA in RLSCs of DW. Previous studies introduced human power as the most valuable asset for enhancing the operational performance of an entity (Mohan & Reddy 2018; Yin, Y, Wang & Lu 2019), including QA (Ossiannilsson 2019). In an early study, Sitkin, Sutcliffe and Schroeder (1994) pointed out that quality is not only about procedures and techniques but also about the people involved in implementing the procedures and techniques and their perceptions. In a QAS, Manghani (2011) mentioned that each employee engaged in the production process should be accountable for performing their job effectively and efficiently while continuously improving it. Previous studies confirmed that skills and competencies development is a basic factor in the success of any quality management (QM) initiative (Kitapçi & Sezen 2007; van Assen 2021). The current study established that periodical training is needed for the development of skills and competencies of workers engaged in both phases of RLSCs of DW. According to Newaz et al. (2020), demolition work is generally more technical; thus, it is difficult to execute without skills and competencies. However, as an interesting finding, the current

study found that building dismantling and on-site processing are demanding employees with skills and competencies developed from years of practical experience in the industry rather than from theoretical and explicit knowledge. In contrast, novices could be engaged in the off-site waste processing phase and, with time, could become experts in the field.

Thus far, asbestos waste should be handled by licensed disposal contractors per the laws and regulations in both developing and developed countries, such as Singapore (Lim et al. 2011); Ghana (Nunoo, Panin & Essien 2018); the Netherlands (Huisman & Van Erp 2013); and the UK (Kupakuwana 2007). Similarly, in Australia (including SA), a nation-wide stringent legal requirement for workers to have a licence is mandatory if they are engaged in asbestos management. Wijewickrama et al. (2022) highlighted that licensing is an information-centric influencing strategy through which regulatory bodies provide information for internal stakeholders in RLSCs on conditions related to managing, controlling and transporting asbestos and contaminated waste from a dismantling site. Through this, workers, especially demolition workers, gained the knowledge of safe removal practices of asbestos while protecting themselves, building occupants and the neighbourhood from asbestos exposure. Therefore, licensing workers, especially those handling asbestos, would be a prerequisite when preparing the 'people' aspect of the supply chain for QA.

The current study posited that it is worthwhile for RLSCs of DW to focus closely on employee involvement as a crucial antecedent of QA. This finding is consistent with previous studies (Sun et al. 2000; Thai & Jie 2018; van Assen 2021) which indicated that the key drivers of QM initiatives and, thereby, of the continuous improvements of an entity are employee involvement and empowerment. For instance, van Assen (2021) argued that employee involvement is related to exploitative learning where empowered employees collect information to ascertain possible discrepancies at work, thus continuously enhancing the quality of their work. In addition, supervising and monitoring are equally important for QA in RLSCs of DW. As an interesting finding, the current study argued that hierarchical supervision and monitoring and employee involvement are interdependent and related in line with social exchange theory (SET), as per the explanation in the study by Thai and Jie (2018). Accordingly, the employer is devoted to supervising and monitoring employees' work by facilitating a favourable working environment; in return, employees will be more committed to extra efforts to offer a high level of quality in their work. However, in positing a contrasting view, many previous studies also asserted that employee involvement could be affected negatively due to monitoring and supervision in the workplace if these approaches

are not cautiously implemented and managed (Chinyamurindi & Tsvangirai 2019; Moussa 2015).

8.2.3 Policy for QA

'Policy' is the third aspect of the integrated system for QA in RLSCs of DW. Policies are authoritative documents that include a set of ideas or plans that would guide the actions and decision making for achieving specific goals in an entity (Rakhmatullaeva & Nurova 2020; Renshaw, Halter & Quinn 2022;). Rakhmatullaeva and Nurova (2020) further explained that policies could be sourced and manifested on different levels, including state or federal, regional and enterprise levels. In line with this, the current study asserted that policies established externally and internally to organisations would guide QA in RLSCs of DW.

As policies established externally to RLSCs of DW, the current study found that, in SA, the *Environmental Protection Act of 1993*, regulations and codes of practice play a crucial role in QA of both demolishers and waste processors. These instruments have been developed and administered by government agencies to provide a stringent regulatory framework accepted by a country's law to guide the practices and actions required for QA. Previous studies highlighted that the government emerges as the most significant influential external stakeholder of RLSCs as it administer legislative instruments that enforce the level of deconstruction (Chinda 2017; Xanthopoulos et al. 2012); the degree of reprocessing (Barros, Dekker & Scholten 1998; Trochu, Chaabane & Ouhimmou 2018); waste management (Chinda 2016; Rinsatitnon et al. 2018); and landfill levy and disposal (Brandão et al. 2021a). In addition to the policies of government bodies, the current study found that contractual instruments administered by the FSC-upstream and -downstream actors on demolishers and waste processors, respectively, could also play a crucial role in promoting QA in RLSCs of DW. However, it was noted that, in most cases, the FSC actors exert tremendous pressure on internal stakeholders through contractual instruments, not for QA but to expedite the job. The current study's findings also highlighted that internal stakeholders and QA in RLSCs of DW have conflicting objectives as pursuing most QA practices is contrary to the cost and time targets of their jobs. Therefore, the QAS will be effective in RLSCs only if stringent legal impositions exist. In line with the statements of Brandão et al. (2021b), the current study posited that, while being a critical driver of QA, the policies established external to the RLSCs of DW, on the other hand, would become a greater barrier for QA if they are inappropriate, ambiguous and incomplete.

In addition to external policies, demolishing and waste processing organisations use a set of internally developed documents to guide the QA of their operations. Fox (2013) mentioned that codes of practice, quality plans and quality manuals are needed for QA in any manufacturing process context. These documents generally consist of mandatory or non-mandatory rules, guidelines and procedures that are essential for QA in repetitive and common practices in the production cycle (Karapetrovic & Willborn 2000). Correspondingly, the current study found that demolishers and waste processors had internally developed quality policies and associated supplementary documents codifying all the rules, guidelines and frameworks needed for QA. All these organisation-based documents had become the guide for developing other project-specific plans and procedures. In an interesting finding, the current study found that organisations engaged in RL activities with third-party accredited quality management systems (QMSs) succeeded in yielding better quality outputs by implementing QA effectively and efficiently. The term 'third-party accreditation' denotes certification given by a third-party body to which the business conforms by following specific quality standards and socially accepted practices and guidelines (Harbaugh, Maxwell & Roussillon 2011; Kim, Hettche & Spiller 2019). Even if third-party accreditation provides organisations with legitimacy and communicates the trustworthiness of their products to customers, a few studies have expressed criticism that accreditation does not always facilitate a QAS that delivers improved process quality (Desai 2018; Dick 2000). Through shedding light on this point, the current study concluded that small and medium-scale organisations engaged in RL operations are unlikely to benefit from the accreditation process mainly due to its extremely formal nature and the associated higher costs.

8.2.4 Technology for QA

'Technology' is the final aspect of the integrated system for QA in RLSCs of DW. Thatcher and Oliver (2001) explained that any production process should benefit from advanced technologies to produce quality output. Correspondingly, the current study found that machines and equipment operated by applying new technologies, such as remote sensing and near infra-red (NIR) spectrometers, facilitated QA in RLSCs of DW. However, compared with findings in the extant body of the literature (see Chapter 2, Subsection 2.4.2.2.4), the RL industry in SA was observed to be lagging behind in embracing novel technologies for QA in their production process. Irrespective of the industry, Scheepens, Vogtländer and Brezet (2016) claimed that the lack of technologies is a crucial barrier to producing high-quality products. O'Connor, Lawrence and Lee (2016) further explained that not only the lack of

technologies but also outdated technologies create more quality issues in products which could lead to product recalls in the production process. Unlike the forward supply chain (FSC), technologies in RLSCs of DW are more complicated and have not experienced development over a prolonged period. Rizos et al. (2016) revealed that the issue in RLSCs was not only the lack of technology but also that organisations are incapable of integrating and using the technologies, especially in small and medium-scale organisations.

As discussed in the above sections, the QAS in an RLSC of DW encompasses a collaborative effort of four aspects: process, people, policy and technology. Even though Wijewickrama et al. (2021b) asserted that all four of these aspects should be integrated within an information-centric environment, their study did not comprehensively explain how this integration should occur. In light of this, the current study found that each aspect of the QAS provided QA with the required useful information. This information should be shared and communicated with other aspects of the system, as shown in Figure 8.1. Therefore, aspects of the QAS are integrated by sharing information generated by each aspect. On this note, the current study empirically established that an information-centric QAS of process, people, policy and technology is needed for RLSCs of DW to produce quality output for the secondary market.

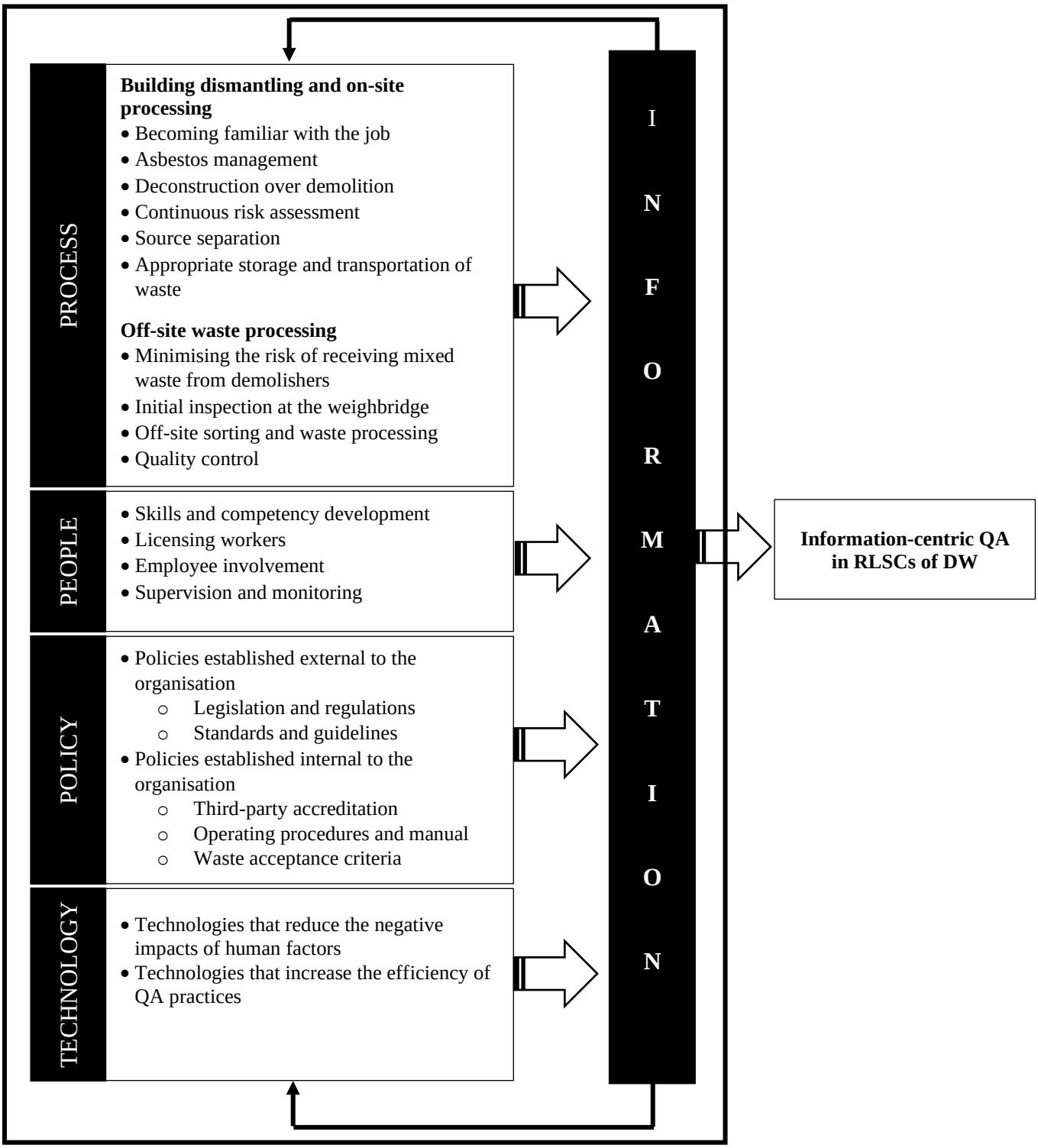


Figure 8.1. Aspects of the information-centric QAS in RLSCs of DW

8.3 Epistemic Uncertainties for QA: From the RLSCs of DW Perspective

The existing body of literature has recurrently outlined that information deficiency is a serious issue in RLSCs of DW (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b). Based on the OIPT perspective, the current study argued that information-deficient epistemic uncertainties (that lead to IPNs) in RLSCs confront information-centric QA in the supply chain. Therefore, it was deemed important to identify the epistemic uncertainties for QA in RLSCs of DW, with this to be fulfilled via Objective 2 (OBJ.2) of the study. Previous studies have revealed that epistemic uncertainties of a supply chain could be manifested as macro-, meso- and micro-level uncertainties (Flynn, Koufteros & Lu 2016; Xu & Song 2022). In line with these studies, the current study confirmed that internal stakeholders in RLSCs encounter different epistemic uncertainties stemming from the external environment (macro-level), the supply chain (meso-level) and internal organisational interactions (micro-level). Accordingly, the demolisher and waste processor in an RLSC each encounter three macro-level, one meso-level and four micro-level uncertainties. The following subsections discuss each level of epistemic uncertainties identified in the semi-structured interviews in the current study's first phase of data collection (see Chapter 4, Section 4.5).

8.3.1 Macro-level uncertainties

Flynn, Koufteros and Lu (2016) asserted that complicated and dynamic situations that are ambiguous and ill-structured have created macro-level uncertainties in the manufacturing industry. The authors further explained that, in situations of macro-level uncertainties, the required information is not available and, at times, the available information changes continuously, which is also congruent with the case of RLSCs in the construction industry. Wijewickrama et al. (2022) found that macro-level uncertainties in RLSCs have evolved due to lapses in the information-centric influencing strategies of external stakeholders of RLSCs of DW. Correspondingly, RLSCs of DW were found to encounter three macro-level uncertainties for QA: regulatory, incentivising and contractual. Notably, these three macro-level uncertainties are common to demolishers and waste processors. In terms of regulatory uncertainties, the current study revealed that the existing immature regulatory system in SA has failed to provide useful information for internal stakeholders in RLSCs of DW. Despite regulations related to CDW management in SA, their primary focus is not on waste management but on protecting the environment and ensuring workers' health and safety. On

the one hand, these regulations have overlapping responsibilities (e.g., asbestos management); on the other hand, none regulates QA practices such as deconstruction and source separation. Furthermore, several government agencies without inter-agency coordination are currently administering these regulations which is a concern also found in most industrialised countries, including China (Yuan 2017) and Saudi Arabia (Blaisi 2019).

The current study also found that external stakeholders in RLSCs incentivise internal stakeholders through subsidising, informing and educating them. Wijewickrama et al. (2022) introduced incentivising as an influencing strategy used by external stakeholders to communicate useful information to internal stakeholders in RLSCs of DW. However, lack of incentivising is the most cited barrier for CDW management in developing and developed countries, including China (Huang, B et al. 2018; Yuan 2017), Saudi Arabia (Blaisi 2019) and Italy (Cristiano et al. 2021). Correspondingly, the current study found that external stakeholders in SA are not adequately subsidising, informing and educating internal stakeholders in RLSCs. For instance, state government agencies have established different subsidising schemes for waste management, none of which is specifically for CDW management. No external stakeholder category is actively engaged in informing and educating internal stakeholders about best practices for QA in RLSCs. In some cases, these stakeholders do not even know they are obligated to raise awareness about waste management in the construction industry. Lack of incentivising is not an issue limited to SA but has also been largely neglected in other jurisdictions (e.g., New South Wales [NSW]) in Australia (Park & Tucker 2017). No previous study has reported this type of uncertainty; thus, the current study conceptualised it as 'incentivising uncertainty'.

Conforming with previous studies (Aschehoug, Boks & Støren 2012; Kembro, Näslund & Olhager 2017), the current study affirmed that the upstream and downstream FSC actors in the value chain have different interests in RLSCs, and this ultimately leads to uncertainties. For instance, as the FSC-upstream actors are not end-users of reprocessed products, they are not interested in contributing to QA in RLSCs. Oschlag-Michael and Datta (2015) noted that contractual uncertainty exists in the information technology (IT) sector when a contract is not informative or is insufficient. Correspondingly, the current study revealed that uninformative and lenient demolition and materials supply contracts in SA had created contractual uncertainties for QA in RLSCs. As their contracts do not promote waste management, the FSC actors avoid monitoring and do not even incorporate NGOs into monitoring internal stakeholders' work as the government does in its projects. Therefore, inadequate monitoring

has compounded the contractual uncertainties for QA in RLSCs. The current study's findings corroborated the findings of past studies which emphasised that builders (i.e., upstream actors) value time and money over waste management and that end-users (i.e., downstream actors) opt for affordable and virgin products over reprocessed products (Cristiano et al. 2021; Park & Tucker 2017). Therefore, the FSC actors do not have an impetus to promote QA in RLSCs; thus, the presence of contractual uncertainties was admissible.

8.3.2 Meso-level uncertainties

The study found that 'management of demolisher's sub-contractors' and 'mixed waste from demolishers' were the meso-level uncertainties experienced by demolishers and waste processors, respectively. Many authors have asserted that sub-contracting makes QM more difficult in the construction industry, especially as the industry is problematic, conflict oriented (Rahimi & Ghezavati 2018) and absorbs profit at different levels (Mkhomazi & Iyamu 2013). In adding a different view, the current study elaborated that sub-contracting is an epistemic uncertainty for QA as the unavailability of information regarding sub-contractors' performance has made their management difficult for demolishers. On the other hand, Tennakoon, Rameezdeen and Chileshe (2022) asserted that the business link between the demolisher and waste processor in RLSCs completely relies on the bulk waste received from demolishers. The current study found that these organisations may achieve a win-win situation if the received waste is clean and well sorted. However, circumstances may occur in which waste processors receive contaminated or mixed waste owing to the poor QA of demolishers and/or issues in the existing regulatory requirements. When mixed waste is received from demolishers, it is considered a meso-level uncertainty for waste processors that would also compound their micro-level uncertainties.

8.3.3 Micro-level uncertainties

Internal stakeholders encountered eight micro-level uncertainties, four each for demolishers and waste processors. 'Health and safety concerns' and 'workflow uncertainties' were common to demolishers and waste processors. In agreement with Banihashemi, Fei and Chen (2019), the current study asserted that depending on the flows of products or materials and aspects of different RL activities, implications for the health and safety dimensions were different for demolishers and waste processors. Thus, 'health and safety concerns' have created epistemic uncertainties to which demolishers and waste processors should respond by undertaking suitable IPMs. As found by van den Berg, Voordijk and Adriaanse (2020),

demolishers encounter workflow uncertainties for coordination of the end-of-life (EoL) phase that stem from the ability to assign skilled personnel (task capabilities) and the number of interdependent tasks (task interdependencies). However, the current study found that 'workflow uncertainties' also affected the QA of both demolishers and waste processors owing to the nature of their RL activities and working procedures, namely, the higher number of exceptions or unanticipated events (i.e., task variability); the extent of having a known procedure (task analysability); and the extent of tasks being dependent upon one another (task interdependencies). Furthermore, the demolisher and waste processor each encounter two micro-level uncertainties exclusively specific to their work. Similar to the findings of van den Berg, Voordijk and Adriaanse (2020) from the perspective of EoL coordination, the current study identified that the lack of information about the existing building condition (i.e., the 'as-is' condition of the building) was an epistemic uncertainty for the QA of demolishers. In addition, the current study emphasised that the 'management of contaminated/hazardous substances' was also an epistemic uncertainty for demolishers which had not been disclosed in previous studies. From the perspective of waste processors, as the production process of reprocessed products is highly labour intensive, 'human errors' are frequent, leading to the unavailability of information and poor information sharing. Furthermore, the complexity of reprocessed products without standard specifications (i.e., product description complexities) also demands that waste processors have high-level interaction with and consolidate information from end-users.

8.4 Impact of Epistemic Uncertainty Propagation on QA in RLSCs of DW

Previous studies highlighted that epistemic uncertainties were not isolated but had interactions (Bhatnagar & Sohal 2005; Busse, Meinlschmidt & Foerstl 2017; de Vasconcelos Gomes et al. 2018; Gales, Porter & Mansour-Cole 1992; Khanmohammadi 2021; Peidro, Mula & Poler 2007). For example, in their seminal study, Gales, Porter and Mansour-Cole (1992) revealed that epistemic uncertainties at the beginning of a project accumulate and form new uncertainties with the execution of the project. In the supply chain context, Peidro, Mula and Poler (2007) mentioned that epistemic uncertainties are propagated along the supply chain, ultimately affecting its performance. Correspondingly, the findings of structured interviews (see Chapter 5) and the focus group discussion (see Chapter 6) in the current study showed that the three levels of epistemic uncertainties for QA in RLSCs of DW interacted and created cause-and-effect relationships. Thus, epistemic uncertainties for QA do not appear as distinct levels but

can be illustrated in an onion diagram. Figure 8.2 presents these onion diagrams of the multi-layered context of epistemic uncertainties of (a) the demolisher and (b) the waste processor.

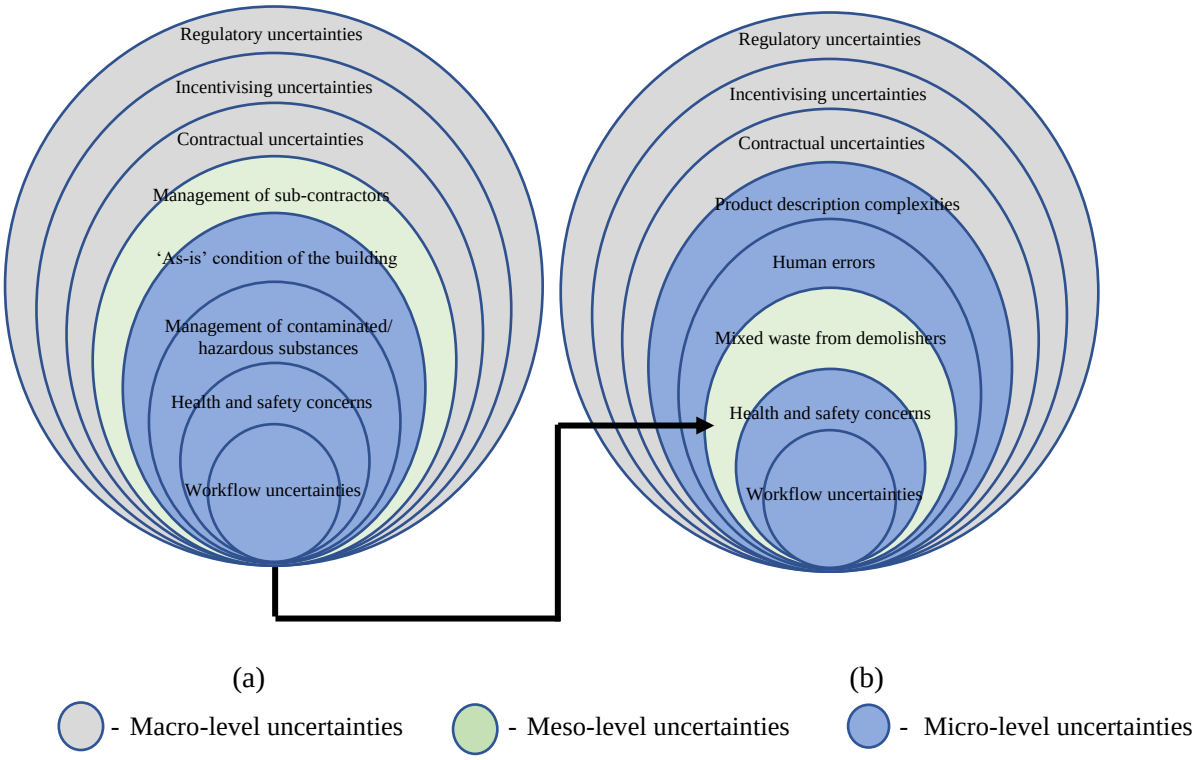


Figure 8.2. Multi-layered context of the epistemic uncertainties of (a) the demolisher and (b) the waste processor

As shown in Figure 8.2, macro-level uncertainties appear in the outer layers of the onion diagrams for the demolisher and waste processor, indicating that they are the root causes for the remaining meso- and micro-level uncertainties. Macro-level uncertainties are represented in three sections: regulatory uncertainties in the outermost layers, followed by incentivising uncertainties and contractual uncertainties. As shown, regulatory uncertainties evolve due to the ineffective aggressive influence of government agencies (Wijewickrama et al. 2022) which is the root cause propagated through incentivising and contractual uncertainties to meso- and micro-level uncertainties. Previous studies have highlighted that RL is implemented in any industry based only on regulatory enforcement (Brandão et al. 2021b; Rebehy et al. 2019). For instance, Rebehy et al. (2019) identified that government regulatory influence is the most critical factor for the implementation of RL for different waste streams in Brazil. Lockrey et al. (2016) mentioned that even if no strong regulatory strategy exists, government control and monitoring activities prevent the illegal dumping of CDW, thereby encouraging waste management in the construction industry in Vietnam. In contrast, the

current study revealed that the absence of a robust regulatory instrument had become a reason why government agencies in SA did not monitor or incentivise RL activities in the construction industry. When no government intervention exists, firstly, NGOs which ally with government agencies to influence the target organisation (Frooman & Murrell 2005) do not have any impetus to incentivise QA in RLSCs. Secondly, the FSC actors, that are always seeking profit maximisation, have no motive to incentivise or contractually influence QA in RLSCs if the government offers no inducement. Thus, the position of regulatory uncertainties in the outermost layers of the onion diagrams in Figure 8.2 is admissible.

From the demolisher's perspective, after macro-level uncertainties, the next layer of the onion diagram represents the meso-level uncertainty, that is, 'management of demolisher's sub-contractors'. This study has argued that macro-level uncertainties, especially regulatory and contractual uncertainties, augment the difficulties of managing sub-contractors which will, in turn, increase the micro-level uncertainties of the demolisher. With this explanation, the position of meso-level uncertainties at the intermediate level of the onion diagrams is admissible, indicating that they influence micro-level uncertainties while being influenced by macro-level uncertainties. Figure 8.2(a) further shows that the demolisher's micro-level uncertainties appear in the inner layers of the onion diagram as they are being influenced by both macro- and meso-level uncertainties. The study found that these micro-level uncertainties were interrelated; thus, they have cause-and-effect relationships. For instance, if the 'as-is' condition of the building cannot be ascertained, the management of contaminated/hazardous substances will undeniably be uncertain for demolishers. Furthermore, if the management of contaminated/hazardous substances is not properly performed, health and safety will certainly be a concern for demolishers. If all these uncertainties exist, it is impossible for the workflow to be smooth and effective for demolishers.

As shown in Figure 8.2, the positioning of meso- and micro-level uncertainties in the waste processor's onion diagram is different to that in the demolisher's diagram. Accordingly, as shown in Figure 8.2(b), two types of micro-level uncertainties appear between the waste processor's macro-level and meso-level uncertainties. The study found that all three macro-level uncertainties created product description complexities for the waste processor. Malone, Yates and Benjamin (1987) described product description complexity as an epistemic uncertainty related to transactions. A complex product without standard specifications is difficult to translate into an unambiguous product description (Dolpanya, Land & Dick 2005;

Premkumar, Ramamurthy & Saunders 2005) which is also the case in RLSCs of DW. In SA, standard specifications are not available exclusively for reprocessed products; instead, the specifications of virgin products are used to ascertain the quality of reprocessed products. For this reason, waste processors have difficulty in understanding end-user requirements of reprocessed products. As found in the body of literature, this global concern has also been observed in countries such as China (Yue 2018) and Hong Kong (Zhang et al. 2019). Previous studies have highlighted that unsupportive government bodies and regulations have been the cause of the unavailability of standards and specifications of reprocessed products or the availability of complicated and difficult-to-understand standards and specifications (Park & Tucker 2017; Shooshtarian et al. 2020; Yue 2018; Zhang et al. 2019). Given this point, the presence of 'product description complexities' after macro-level uncertainties in the waste processor's onion diagram is admissible. Kolus, Wells and Neumann (2018) posited that when the complexity of products increases and customer expectations are poorly documented, the vulnerability to human errors in the production process is heightened, irrespective of the industry. In line with this statement, the current study found that product description complexities cause human errors in RLSCs of DW; thus, 'human errors' was positioned in the layer following 'product description complexities'. After these micro-level uncertainties (product description complexities and human errors), the waste processor's meso-level uncertainty, that is, 'mixed waste received from demolishers', appears in the onion diagram, as shown in Figure 8.2(b). It is worth highlighting that 'mixed waste received from demolishers' is the epistemic uncertainty that bridges the demolisher's and waste processor's epistemic uncertainties. As is apparent from Figure 8.2(b), the reasons for waste processors receiving mixed waste from demolishers are twofold. As this is part of the RLSC process, namely, the output of the dismantling and on-site processing phase, which is the starting point of the supply chain, will become input to the subsequent off-site waste processing phase (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018). Consequently, the first reason is that the compounding effect of the demolisher's epistemic uncertainties ultimately produces mixed waste at the end of the building dismantling and on-site processing phase which would then become input for the waste processor's business. The second reason is that, even if mixed waste is carried forward, waste processors should be able to distinguish it in advance and prevent it from entering their MRF. The current study thus found that the compounding effect of the waste processor's macro-level uncertainties, product description complexities and human errors augments the possibility of mixed waste being accepted into MRFs by waste processors. As in the demolisher's onion diagram, the

waste processor's onion diagram's inner two layers successively represent health and safety concerns and workflow uncertainties.

As explained in this section, the macro-, meso- and micro-level uncertainties of each of the demolisher and waste processor are positioned layer by layer in the onion diagrams in Figure 8.2, indicating how they relate to each other. In summary, it is evident that epistemic uncertainties for QA not only create interactions between macro, meso and micro levels but are also propagated from the building dismantling and on-site processing phase to the off-site processing phase in the sequence of operations carried out through RLSCs of DW.

8.5 IPMs for QA: From the RLSCs of DW Perspective

The key tenet of the OIPT is information processing. In line with the theoretical foundation of the OIPT, appropriate IPMs should be undertaken in response to IPNs arising from epistemic uncertainties to achieve operational performance criteria, such as QA, whereas mismatches jeopardise performance (Galbraith 1973, 1974). Accordingly, through the semi-structured interviews (see Chapter 4, Section 4.6), the current study posited 15 diverse IPMs that internal stakeholders could deploy in response to macro-, meso- and micro-level uncertainties. Complying with the definition of information processing by Tushman and Nadler (1978), these IPMs were described as mechanisms that internal stakeholders could undertake to gather, interpret and synthesise information to successfully respond to epistemic uncertainties. The findings of the structured interviews (see Chapter 5, Section 5.5) showed that some IPMs could be undertaken in response to many of the epistemic uncertainties of both the demolisher and waste processor. For instance, 'rules and programs' could be undertaken in response to all the epistemic uncertainties for QA in RLSCs of DW. Through the findings of the structured interviews (see Chapter 5) and the focus group discussion (see Chapter 6), the current study established that as epistemic uncertainties could create cause-and-effect relationships, an IPM's effect in responding to a particular epistemic uncertainty could also be exerted on other epistemic uncertainties linked to the earlier uncertainty. The current study thus established that undertaking appropriate IPMs in response to epistemic uncertainties at the root cause level would be more effective in avoiding the occurrence of the remaining epistemic uncertainties that would be caused due to the former uncertainty. Previous studies by Jayasinghe (2019) and Qazi et al. (2018) presented a similar statement.

Figure 8.3 presents the multi-layered context of IPMs undertaken by (a) the demolisher and (b) the waste processor in response to their epistemic uncertainties for QA. As macro-level

uncertainties appear at the root cause level, stemming from issues in the external environment beyond the control of internal stakeholders in RLSCs of DW, only a few IPMs could be undertaken in response, as shown in Figure 8.3. Wijewickrama et al. (2021c) identified three measures: (i) reforming regulatory instruments; (ii) employing effective incentivising schemes; and (iii) active employment of FSC actors to minimise macro-level uncertainties from external stakeholders' perspectives. The authors argued that it would be effective to minimise macro-level uncertainties at their source rather than when they become a menace to internal stakeholders. Moreover, Namada (2018) claimed that organisations should always scan their environments to understand the changes, new technologies and changing customers and adapt accordingly. Wijewickrama et al. (2021c) expressed the view that even if external stakeholders undertake mechanisms at their source to avoid macro-level uncertainties for QA, no guarantee is available that these uncertainties can be completely avoided. However, their study did not indicate how internal stakeholders in RLSCs of DW could respond to macro-level uncertainties. In shedding light on this point, the current study found that demolishers and waste processors could only develop internal policies, procedures, guidelines and frameworks (rules and programs) in response to regulatory uncertainties that occur from concerns beyond their control. Similarly, as shown in Figure 8.3, in response to each of the incentivising and contractual uncertainties, demolishers and waste processors could make alliances with each other (business partnering) and plan extensively and define targets (planning and goal setting), respectively. Notably, when these three IPMs are undertaken in response to macro-level uncertainties, they will also respond to all the remaining meso- and micro-level uncertainties of demolishers and waste processors. The early seminal study by Daft and Lengel (1986) identified that IPMs, such as 'rules and programs', 'business partnering' and 'planning and goal setting', are less rich and more impersonal (i.e., they do not have any reference or connection to a particular person), are IPMs that provide standard information in response to epistemic uncertainties. Therefore, they are applicable for undertaking in response to known issues that recurrently occur (Daft & Lengel 1986; Galbraith 1973). The current study compounded this proposition, identifying that these IPMs are also suitable for responding to uncertainties, such as macro-level uncertainties, that originate from reasons beyond the control of internal stakeholders.



Figure 8.3. Multi-layered context of the IPMs of (a) the demolisher and (b) the waste processor

The study found that demolishers and waste processors form contracts in response to their meso-level uncertainties, other than undertaking common IPMs such as rules and programs,

planning and goal setting, and business partnering. Previous studies highlighted that, on the one hand, forming contracts is an information-centric influencing strategy that provides essential information (Wijewickrama et al. 2022) while, on the other hand, lapses in this strategy would create uncertainties due to missing information (Oschlag-Michael & Datta 2015; Wijewickrama et al. 2021c). Therefore, it is important to emphasise that, while forming contracts is an appropriate IPM, it tends to be uncertain if the contract is not appropriately compiled. In addition, some IPMs specific to demolishers and waste processors could be undertaken to address their meso-level uncertainties. For instance, 'group meetings' and 'performance evaluation of sub-contractors' are acceptable for undertaking in response to difficulties of managing sub-contractors. On the other hand, implementing strict 'waste acceptance criteria/gate fees' and creating 'integrator roles' (i.e., Accounts Managers) are effective IPMs that waste processors could undertake in response to their meso-level uncertainty, that is, 'mixed waste received from demolishers'.

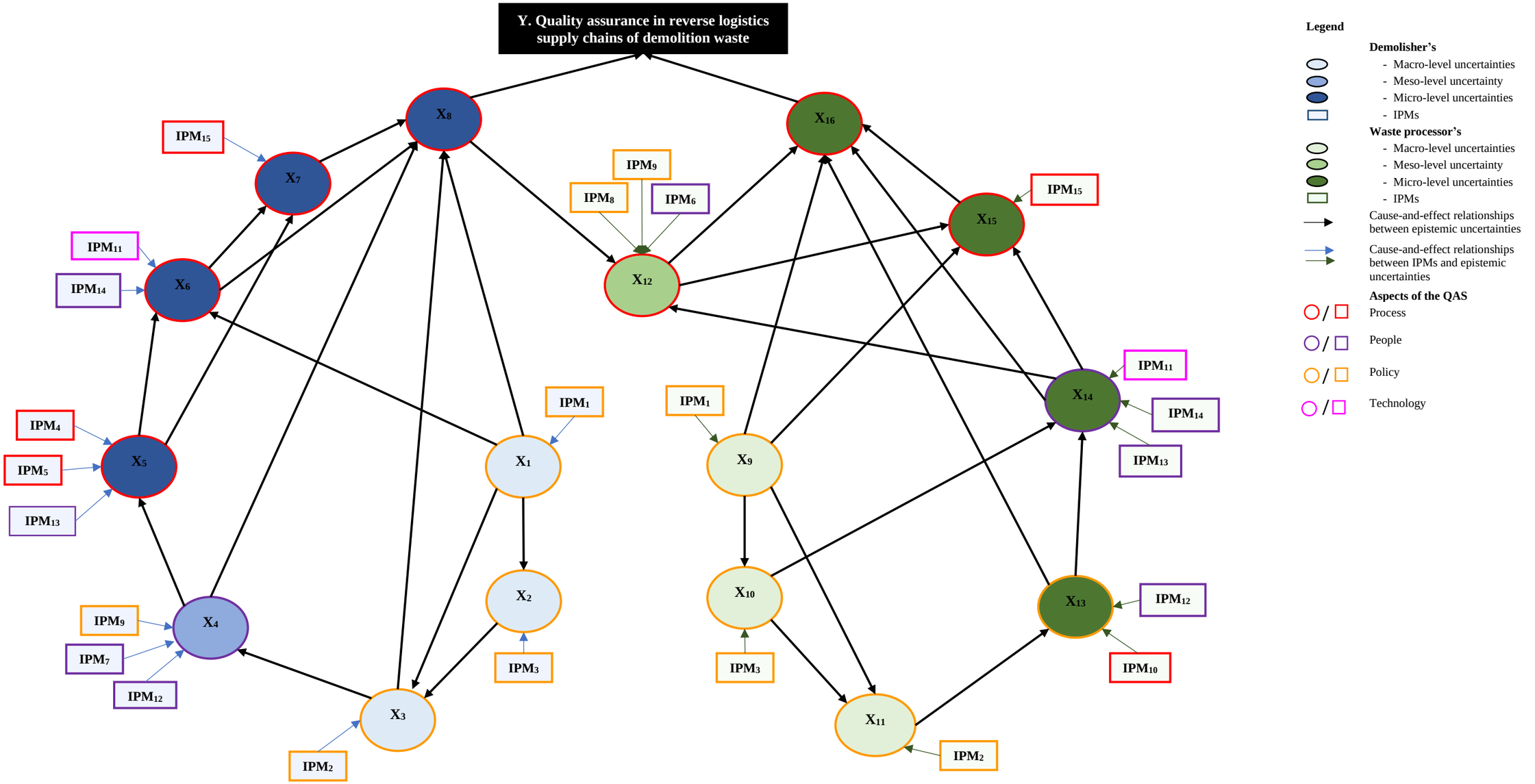
Many IPMs, besides 'rules and programs', 'planning and goal setting' and 'business partnering', could be employed by demolishers and waste processors in response to their micro-level uncertainties. The current study, corroborating the findings of van den Berg, Voordijk and Adriaanse (2020), found that the 'collection of building documents and asbestos registers' and 'site visits/pre-demolition audits' were IPMs that only demolishers would undertake, especially in response to their micro-level uncertainty: ''as-is' condition of the building'. On the other hand, 'creation of special reports' (i.e., studies and/or surveys that gather data about an issue) is an IPM that waste processors employed in response to their micro-level uncertainties, especially 'product description complexities'. In addition, many IPMs, such as 'group meetings', 'hierarchical referral', 'incorporation of self-contained groups', 'investment in technologies' and 'creation of slack resources', could be undertaken by demolishers and waste processors in response to micro-level uncertainties. Notably, Galbraith (1973, 1974) described all these IPMs as organisational design actions, advocating for stakeholders to respond successfully when the uncertainty level increased. The author further mentioned that some of these IPMs, such as 'creation of slack resources' and 'incorporation of self-contained groups', reduced the amount of information to be processed. On the other hand, the remaining IPMs increased the IPCs. Furthermore, Daft and Lengel (1986) indicated that some IPMs, such as 'group meetings' and 'hierarchical referral', were face-to-face (i.e., personal) IPMs that used rich media to respond promptly, with this

especially depending on the issue. Therefore, these IPMs were more effective to implement when the uncertainty level increased as they enabled immediate feedback.

8.6 Information Processing for QA in RLSCs of DW

With the urgent need to produce quality reprocessed products in the construction industry, the current study contributed insights on improving QA in RLSCs of DW through information processing. An information processing model for QA in RLSCs of DW was developed to achieve the study's Objective 3 (OBJ.3), consolidating all findings from the three sequential data collection phases, that is, semi-structured interviews (see Chapter 4), structured interviews (see Chapter 5) and the focus group discussion (see Chapter 6). The information processing model for QA (see Figure 8.4) outlines the relationships between aspects of the QAS, epistemic uncertainties and IPMs for QA in RLSCs of DW. To achieve the study's Objective 4 (OBJ.4), this information processing model for QA was applied in two cases during the final data collection phase (see Chapter 7 for the findings). These two cases were RLSCs, one with a large-scale demolisher and waste processor and the other with a small and medium-scale demolisher and waste processor (see Chapter 3, Subsection 3.5.1.4)

The current study found that RLSCs of DW, whether they comprised large-scale or small and medium-scale demolishers and waste processors, were vulnerable to the 16 epistemic uncertainties in the information processing model for QA. Previous studies mentioned that small and medium-scale organisations generally encounter greater epistemic uncertainties than large-scale organisations, especially those uncertainties that stem from the external environment (i.e., macro-level uncertainties) (Baporikar, Nambira & Gomxos 2016; Sopha, Jie & Himadhani 2021). According to Baporikar, Nambira and Gomxos (2016), the reason for this is that small and medium-scale organisations have limited capabilities to predict or distinguish external changes that will hinder organisational performance. The current study, in going beyond this statement, found that in the context of RLSCs of DW, compared to large-scale organisations, the small and medium-scale organisations were more vulnerable not only to macro-level uncertainties but also to meso- and micro-level uncertainties. Of all the epistemic uncertainties, RLSCs with small and medium-scale organisations were found to be more susceptible to the waste processor's meso-level uncertainty, that is, 'mixed waste received from demolishers'.



Epistemic uncertainties				Information processing mechanisms			
X_1	Regulatory uncertainties of the demolisher	X_9	Regulatory uncertainties of the waste processor	IPM_1	Rules and programs	IPM_9	Forming contracts
X_2	Incentivising uncertainties of the demolisher	X_{10}	Incentivising uncertainties of the waste processor	IPM_2	Planning and goal setting	IPM_{10}	Creation of special reports
X_3	Contractual uncertainties from FSC-upstream actors	X_{11}	Contractual uncertainties from FSC-downstream actors	IPM_3	Business partnering	IPM_{11}	Investment in technologies
X_4	Management of demolisher's sub-contractors	X_{12}	Mixed waste received from demolishers	IPM_4	Collection of building documents and asbestos registers	IPM_{12}	Group meetings
X_5	'As-is' condition of the building	X_{13}	Product description complexities	IPM_5	Site visits/pre-demolition audits	IPM_{13}	Hierarchical referral
X_6	Management of contaminated/hazardous substances	X_{14}	Human errors	IPM_6	Creation of integrator roles	IPM_{14}	Incorporation of self-contained groups
X_7	Health and safety concerns of the demolisher	X_{15}	Health and safety concerns of the waste processor	IPM_7	Performance evaluation of sub-contractors	IPM_{15}	Creation of slack resources
X_8	Workflow uncertainties of the demolisher	X_{16}	Workflow uncertainties of the waste processor	IPM_8	Waste acceptance criteria/gate fees		

Figure 8.4. Information processing for QA in RLSCs of DW

Notably, RLSCs with large-scale organisations were also highly vulnerable to ‘mixed waste received from demolishers’, even if the probability of occurrence was low compared to that of small and medium-scale RLSCs. It was also found that ‘mixed waste received from demolishers’ was one of the top five epistemic uncertainties to which QA was most sensitive in RLSCs of DW, irrespective of whether they wre comprised of large-scale or small and medium-scale organisations. As shown in Figure 8.4, the compounding effect of the demolisher’s epistemic uncertainties generated bulk mixed waste which, if transported to an MRF, significantly increased the waste processor’s micro-level uncertainties. Previous studies have expressed the criticism that, even if mechanical demolition saves time and cost, it generates huge stockpiles of mixed waste which cannot be easily sorted (Forsythe & Fini 2018; Roussat et al. 2008; Tennakoon, Rameezdeen & Chileshe 2022). The unsorted or mixed piles of waste, including contaminants, are often not accepted for reprocessing; instead, they are directly dumped illegally or at landfill sites (Roussat et al. 2008). However, as in any waste management sector, informal ‘scavengers’ engaged in DW management adopt fast-track approaches to demolition and unprofessionally send mixed waste to MRFs to avoid paying extremely high landfill disposal levies (Wijewickrama et al. 2021a). If mixed waste is received and accepted into MRFs, low-quality products would be the output thus ending the waste processor’s business (Noguchi, Park & Kitagaki 2015). On this note, the significance of mixed waste received from demolishers as an epistemic uncertainty for QA in RLSCs of DW is admissible.

Agburu, Anza and Iyortsuun (2017) outlined that small and medium-scale organisations always seek to minimise their cost of operations. Therefore, they sub-contract most of their jobs to third parties who specialise in that area, thus, being able to complete the assigned task efficiently. Correspondingly, the current study found that due to the lack of continuous job assurance, most demolishers, especially the small and medium-scale ones, sub-contracted most of their jobs to specialised third-party sub-contractors. However, ‘management of the demolisher’s sub-contractors’, a demolisher’s meso-level uncertainty, had the least vulnerability, of all epistemic uncertainties, of occurring in RLSCs with small and medium-scale organisations. On the other hand, of all epistemic uncertainties, the least vulnerable epistemic uncertainty experienced by large-scale demolishers and waste processors was ‘incentivising uncertainties’. This emphasised that compared to small and medium-scale organisations, large-scale organisations in

RLSCs in SA were receiving adequate incentives from regulatory bodies and other external bodies. The body of literature has recurrently highlighted that small and medium-scale organisations in both developed and developing countries are confronted with many challenges, such as difficulty in obtaining credit facilities and grants and lack of infrastructure and government incentives (Marri, Nebhwani & Sohag 2011; Ntiamoah, Li & Kwamega 2016). These challenges make it difficult for small and medium-scale organisations to survive in the industry even if they bring economic growth into a country (Ntiamoah, Li & Kwamega 2016) which is also the case for RLSCs of DW in SA. On this note, the current study posited that small and medium-scale organisations would play a promising role in promoting RL in the construction industry if government incentives helped them to gain access to capital, new technologies, skill developments and secondary markets.

Even if the 16 IPMs found by the current study could be undertaken in response to epistemic uncertainties, RLSCs with small and medium-scale organisations could not undertake all of them. For instance, it was found that they seldom undertook IPMs such as business partnering (demolisher and waste processor), forming contracts with demolishers (waste processor), creation of integrator roles (waste processor) and creation of special reports (waste processor). Sopha, Jie and Himadhani (2021) asserted that small and medium-scale organisations should consider minimising or avoiding uncertainties more than large-scale organisations. Ghosal and Ye (2015) provided empirical evidence that uncertainties negatively impact on the operational performance of small and medium-scale organisations but do not exist or are weaker in their effect on the operational performance of large-scale organisations. The authors further demonstrated that uncertainties adversely influence new product developments which are crucial for the survival and development of small and medium-scale organisations. Nevertheless, even after small and medium-scale organisations undertook IPMs, the current study found that RLSCs comprising these organisations were experiencing less satisfaction with QA than RLSCs comprising large-scale organisations. They were found to be highly vulnerable to product description complexities, even after undertaking all the IPMs. In the manufacturing industry, small and medium-scale organisations always seek to develop diverse portfolios of products to augment their sales growth, competitiveness and survival in the market (Divakara & Surangi 2021; Fernhaber & Patel 2012). Developing a vast array of products has led to product

description complexities and, consequently, information processing difficulties in small and medium-scale organisations (Closs et al. 2008; Fernhaber & Patel 2012). However, in the context of RLSCs of DW in SA, it was found that product description portfolios of large-scale waste processors were more advanced and complicated than those of small and medium-scale waste processors. Most small and medium-scale waste processors in SA specialise in producing recycled concrete pavement materials and aggregates. In the same vein, it was evident that even if large-scale waste processors experienced high product description complexities, they responded to them more appropriately, especially by gathering customer feedback through varied studies and surveys (i.e., creation of special reports). As small and medium-scale ones did not often undertake this IPM, their high vulnerability to product description complexities (even after undertaking all the IPMs) is admissible. Organisations in RLSCs of DW, whether small and medium scale or large scale, are found to be more effective in reducing the uncertainties arising from the ‘‘as-is’ condition of the building’ by undertaking appropriate IPMs. As revealed by van den Berg, Voordijk and Adriaanse (2020), the acquisition of building documents and site visits are appropriate for assessing the ‘as-is’ condition of the building; however, these mechanisms are not adequate when unexpected building parts are present. In light of this, the current study found that, in addition to collecting building documents and asbestos registers and site visits/pre-demolition audits, hierarchical referral is an appropriate mechanism for information processing if unexpected building parts are present in the building to be demolished. Moreover, the IPMs that could be undertaken in response to the epistemic uncertainties which directly or indirectly cause the ‘‘as-is’ condition of the building’ (see Figure 8.4) also advocate reducing its level of uncertainty.

Sopha, Jie and Himadhani (2021) highlighted the importance of understanding the root causes of uncertainties to decide and undertake appropriate mechanisms to coping with and mitigate them, thus leading to improved performance. In line with this, the current study found that, rather than the waste processor’s uncertainties, the demolisher’s uncertainties were more significant; thus, they acted as root cause uncertainties in influencing QA in RLSCs of DW. As an RLSC of DW is an interrelated process, the operational performance of the building dismantling and on-site processing phase decides the effectiveness of the subsequent off-site waste processing phase (Jayasinghe, Rameezdeen & Chileshe 2022; Tennakoon, Rameezdeen & Chileshe 2022). Previous

studies have confirmed that the dismantling work is more technical, as it handles the bulk of EoL salvageable waste (Govindan, Soleimani & Kannan 2015; Newaz et al. 2020). Therefore, the current study raised the importance of managing the demolisher's epistemic uncertainties, which would minimise the waste processor's uncertainties and ultimately enhance QA in RLSCs of DW. Of all three levels of epistemic uncertainties, macro-level uncertainties were found to be the most crucial for managing QA in RLSCs of DW. As shown in Figure 8.4, all macro-level uncertainties of both demolishers and waste processors appeared as root causes of the remaining uncertainties. Even though it is important to treat and mitigate root cause variables (Jayasinghe 2019; Qazi et al. 2018; Sopha, Jie & Himadhani 2021), root cause uncertainties in the current study's context were found to be the most difficult to manage. The two reasons are: firstly, the macro-level uncertainties for QA have evolved due to lapses in the influencing strategies of external stakeholders (Wijewickrama et al. 2022) which are beyond the control of internal stakeholders in RLSCs of DW. Secondly, rather than responding to IPMs, these macro-level uncertainties are more responsive to the strategies that external stakeholders could undertake. These include: (i) reforming regulatory instruments; (ii) employing effective incentivising schemes; and (iii) active employment of FSC actors (Wijewickrama et al. 2021c) which will take a prolonged time to plan and implement. The current study found that a few IPMs, such as 'rules and programs' and 'planning and goal setting', were more effective in responding to macro-level uncertainties for QA in RLSCs of DW. Notably, 'business partnering', an IPM undertaken in response to 'incentivising uncertainties', was not very effective for responding: it was also an IPM only undertaken in RLSCs with large-scale organisations.

Figure 8.4 shows the cause-and-effect relationships between epistemic uncertainties in the information processing model developed in the current study for QA in RLSCs of DW. Section 8.4 discussed the rationale behind the cause-and-effect relationships between epistemic uncertainties, considering these as they appeared in the layers of an onion diagram. Figure 8.4 also illustrates the IPMs that could be undertaken in response to IPNs arising as a result of the epistemic uncertainties of demolishers and waste processors, which are also discussed in Section 8.5. In an interesting finding, the current study found that both epistemic uncertainties and IPMs represent each aspect of the QAS: process, people, policy and technology (see Figure 8.4). Even if Wijewickrama et al. (2021a) asserted that an information-centric environment should be available to

integrate process, people, policy and technology aspects in the QAS in an RLSC of DW, their study did not explain in detail how this integration should take place. On this note, the current study elucidated a new interpretation in which aspects of the QAS themselves were accountable for creating the information-centric environment needed for them to be integrated for the purpose of QA. On the one hand, it was found that the shortcomings in aspects of the QAS were leading to creating epistemic uncertainties for QA. On the other hand, the same aspects of the QAS were responsible for creating mechanisms that enabled information processing to confront epistemic uncertainties for QA in RLSCs of DW. It is apparent from Figure 8.4 that when epistemic uncertainties evolved due to shortcomings of a particular aspect in the QAS, in most cases, the same aspect was responsible for developing IPMs in response to those uncertainties. For instance, macro-level uncertainties and their associated IPMs represent the 'policy' aspect of the QAS. However, this observation is not common for all epistemic uncertainties and IPMs. Accordingly, circumstances could occur in which IPMs could be undertaken in response to some epistemic uncertainty representing a different aspect of the QAS which was not responsible for creating the uncertainty. Even if the RL industry in SA is lagging behind in embracing novel technologies, interestingly, none of the epistemic uncertainties was found to arise due to the lapses or issues in the aspect of 'technology' in the QAS. Since RLSCs are mostly labour-intensive (Rašković et al. 2020; Yuan et al. 2022), it is admissible to find that hardly adopting new technologies has not created epistemic uncertainties for the QA of RLSCs in SA. However, even if the aspect of 'technology' does not create any epistemic uncertainties, an IPMs source from it could undertake in responding to the epistemic uncertainties that occur due to other aspects of the QAS. Given this, it becomes evident that the aspect of 'technology' plays a significant role in QA in RLSCs of DW as it does not create any of the epistemic uncertainties but creates appropriate IPMs to respond to the other epistemic uncertainties which evolve due to the other aspects in QAS.

8.7 Concluding Remarks

This chapter outlined the discussion of the research findings beginning, firstly, with findings on the broader aspects of the QAS in RLSCs of DW. The discussion presented the empirical establishment of how process, people, policy and technology contributed to QA in RLSCs of DW. Secondly, the chapter discussed findings on the epistemic uncertainties for QA and how they are propagated to affect QA. The propagation of

epistemic uncertainties of the demolisher and the waste processor was discussed using onion diagrams (see Figure 8.3) to represent their multi-layered context. From the demolisher's and waste processor' perspectives, macro-level uncertainties appeared as root causes propagated to create meso- and micro-level uncertainties. Thirdly, the chapter discussed findings on IPMs that could be undertaken in response to IPNs arising from epistemic uncertainties. The chapter discussed information processing for QA in RLSCs of DW. It then determined that aspects of the QAS themselves were responsible for creating the integrated information-centric environment needed for QA in RLSCs of DW. The next chapter concludes the thesis by summarising the key findings against each objective and outlining the study's contributions to the body of knowledge, its practical implications, its limitations and recommendations for future research.

9 Conclusion

9.1 Introduction

This chapter concludes this research by revisiting the objectives and discussing the degree to which they have been achieved in the current study. The chapter first reflects on the major research findings under each of the study's objectives. The following sections outline the study's contributions to the body of knowledge and its practical implications. The chapter then discusses the study's limitations and recommendations for future research.

9.2 Summary of Key Findings

The aim of this research was to develop and empirically validate an information processing model by identifying and assessing the interrelationships between epistemic uncertainties for QA in RLSCs of DW. Four objectives were formulated to achieve this research aim which was subsequently accomplished by conducting sequential four-phase data collection methods (see Chapter 3). The following subsections summarise research findings under each objective of the current study.

9.2.1 Objective 1: To establish how process, people, policy and technology contribute to QA

Chapter 4 presents the findings from collected data to achieve Objective 1 (OBJ.1). Under Objective 1, the current study empirically established how the aspects, process, people, policy and technology contribute to QA in RLSCs of DW in the South Australian context. The contributions of these aspects for QA were separately discussed during the two phases of RLSCs of DW: the building dismantling and on-site processing phase and the off-site waste processing phase. In general, even though each of these aspects exists in isolation, the current study, in an interesting finding, determined that they should be interrelated to create an integrated system for QA in RLSCs of DW.

Under ‘process’, the first aspect of the QAS, the study identified the practices that should be undertaken for QA in RLSCs of DW. Accordingly, becoming familiar with the job, asbestos management, deconstruction over demolition, continuous risk assessment, source separation, and appropriate storage and transportation of waste were QA practices that should be undertaken during the building dismantling and on-site processing phase. Similarly, minimising the risk of receiving mixed waste from demolishers, initial inspection at the weighbridge, off-site sorting and waste processing, and quality control were the practices for QA that should follow during the off-site waste processing phase. Interestingly, all these QA practices appeared in the sequence of operations in RLSCs of DW. ‘People’ was the second aspect of the QAS. The study found that people who were engaged in the operations of RLSCs of DW should be competent to conduct QA practices within a regulatory framework with the adoption of new technologies or the use of existing technologies. As an important point, on the one hand, the building dismantling and on-site processing phase valued people with years of experience ahead of qualifications. On the other hand, off-site waste processing was seeking qualified people with knowledge of QA practices, technologies and policies relevant to their job roles. Furthermore, the study found supervision and monitoring and employee involvement to be important criteria for making the aspect of ‘people’ ready for QA in RLSCs of DW. ‘Technology’ was another crucial aspect of the QAS, with this needed to reduce the negative impacts of human factors while increasing the efficacy of QA practices. ‘Process’ and ‘people’ aspects would become more efficient and effective when the production process embraced high-tech machines and equipment. Notably, the application of technologies should be undertaken in compliance with the policies that regulate QA in RLSCs of DW. ‘Policy’ was the final aspect of the QAS in RLSCs of DW. The study found two types of policies were needed for QA in RLSCs of DW: (i) policies that were established internal to the supply chain and (ii) policies that were established external to the supply chain. The quality policies and associated supplementary documents, including all the rules, guidelines and frameworks, were considered internal policies for QA in RLSCs of DW. The study highlighted the importance of receiving third-party accreditation/assurance for the QASs of organisations in RLSCs of DW. Furthermore, external policies included legislation, regulations, standards, guidelines and forms of contracts developed by external stakeholders of the supply chain, such as regulatory bodies and FSC actors. The study found that all people engaged in RLSCs should be competent to conduct all

practices in the QA process by embracing new or existing technologies within the stringent framework defined by the policies for QA in RLSCs of DW.

Under this objective, in an interesting finding, the current study found that each aspect of the QAS provided useful information needed for QA. This information should be shared and communicated with the other aspects of the QAS to create an integrated system for QA in RLSCs of DW. On this note, the current study empirically established that an information-centric system of process, people, policy and technology was needed for QA in RLSCs of DW to produce quality output for the secondary market.

9.2.2 Objective 2: To identify epistemic uncertainties that lead to IPNs and corresponding IPMs for QA

Based on the OIPT, the current study completely built upon the conceptualisation that demolishers and waste processors in RLSCs of DW were information processing systems that encountered epistemic uncertainties for QA. Thus, in response to Objective 2 (OBJ.2), the study found that each internal stakeholder experienced eight epistemic uncertainties for QA. As the OIPT further posited, these organisations should undertake appropriate IPMs to match the IPNs that evolved due to epistemic uncertainties; if not, the mismatches would jeopardise operational performance criteria, such as QA. Accordingly, the current study found 15 IPMs that internal stakeholders could undertake in response to epistemic uncertainties for QA in RLSCs of DW.

The study affirmed that internal stakeholders in RLSCs encountered three types of epistemic uncertainties stemming from different levels of the supply chain: (i) macro-level (from the external environment); (ii) meso-level (from the supply chain), and (iii) micro-level (due to internal organisational interactions). Accordingly, both the demolisher and waste processor in an RLSC of DW encountered three macro-level, one meso-level and four micro-level uncertainties. For macro-level uncertainties, both the demolisher and waste processor encountered ‘regulatory’, ‘incentivising’ and ‘contractual’ uncertainties. These macro-level uncertainties evolved due to lapses in the information-centric influencing strategies of external stakeholders of RLSCs of DW. Thus, they were beyond the control of internal stakeholders in RLSCs of DW. Furthermore, ‘management of the demolisher’s sub-contractors’ and ‘mixed waste received from demolishers’ were the meso-level uncertainties encountered by the demolisher and the waste processor, respectively. These uncertainties stemmed from the

supply chain; thus, they were within the realm of control of the specific internal organisation. For micro-level uncertainties, both the demolisher and waste processor encountered ‘health and safety concerns’ and ‘workflow uncertainties’. In addition, each of the demolisher and waste processor encountered two micro-level uncertainties that were specific to their work. For instance, the ‘‘as-is’ condition of the building’ and ‘management of contaminated/hazardous substances’ were the micro-level uncertainties exclusive to demolishers, while ‘product description complexities’ and ‘human errors’ were exclusive to waste processors. These micro-level uncertainties stemmed from the interactions of each internal stakeholder organisation in an RLSC of DW.

The study found 15 IPMs that could be undertaken in response to epistemic uncertainties. Some IPMs were common to both demolishers and waste processors, whereas others were specific to one or the other. For instance, demolishers and waste processors undertook ‘rules and programs’, ‘planning and goal setting’ and ‘business partnering’ in response to all epistemic uncertainties irrespective of whether they originated from the macro, meso or micro levels. Notably, these were the only IPMs that could be undertaken against macro-level uncertainties of both demolishers and waste processors. The contractual form of IPMs, such as ‘forming contracts’, responded effectively to meso-level uncertainties of both demolishers and waste processors. Furthermore, a few IPMs exclusive to demolishers and waste processors could also be undertaken against meso-level uncertainties. For instance, ‘creation of integrator roles’ and ‘waste acceptance criteria/gate fees’ were IPMs that only waste processors could undertake against their meso-level uncertainty of ‘mixed waste received from demolishers’. Similarly, ‘performance evaluation of sub-contractors’ was an IPM that only demolishers could undertake in response to their meso-level uncertainty related to managing sub-contractors. In addition to ‘rules and programs’, ‘planning and goal setting’ and ‘business partnering’, both demolishers and waste processors mostly undertook common IPMs in responding to micro-level uncertainties. For example, ‘investment in technologies’, ‘creation of slack resources’, ‘group meetings’, ‘hierarchical referral’ and ‘incorporation of self-contained groups’ were the IPMs that both internal stakeholder organisations could undertake against their macro-level uncertainties. Other than these common IPMs, demolishers and waste processors also undertook a few exclusive IPMs that were specific to them in responding to micro-level uncertainties. Accordingly, ‘collection of building documents and asbestos registers’

and ‘site visits/pre-demolition audits’ were IPMs that only demolishers could undertake against their micro-level uncertainties, while ‘creation of special reports’ was an IPM that only waste processors could undertake against their micro-level uncertainties.

Under this objective, in an interesting finding, the current study found that all epistemic uncertainties and IPMs represented the aspects of the QAS: process, people, policy and technology (see Chapter 4, Table 4.5 and Chapter 8, Figure 8.4). Thus, the study elucidated that an integrated system of process, people, policy and technology was responsible for creating an information-centric environment that would successfully respond to epistemic uncertainties created by the same aspects. On the one hand, shortcomings in aspects of the QAS were found to lead to creating epistemic uncertainties for QA. On the other hand, those aspects of the QAS were responsible for creating mechanisms that enabled information processing to confront epistemic uncertainties for QA in RLSCs of DW. Based on these findings, the study posited its insights into how effectively process, people, policy and technology aspects could contribute to responding to epistemic uncertainties for successful QA in RLSCs of DW.

9.2.3 Objective: 3: To develop an information processing model for QA and to empirically validate the model

The third objective of the research was to develop an information processing model for QA in RLSCs of DW and to empirically validate the model. Chapters 5 and 6 present the findings collected to achieve Objective 3 (OBJ.3). Variables of this information processing model comprised the epistemic uncertainties and IPMs identified to accomplish Objective 2 (OBJ.2). The interrelationships between these variables were important for developing this information processing model. The study used BBN analysis as the modelling technique to develop the information processing model for QA as it advocates for effectively visualizing causal relationships between variables in complex settings enabling both forward and back propagation analyses (see Chapter 3, Subsection 3.5.2.3). Accordingly, first, a causal map was developed from the structured interviews, including the cause-and-effect relationships between: (i) epistemic uncertainties that lead to IPNs; (ii) epistemic uncertainties and the performance measurement criterion (i.e., QA); and (iii) IPMs and epistemic uncertainties. The causal map was then transformed into a BBN-based conceptual information processing model, based on the principles of the causal mapping approach, comprising eliminating circular relationships; distinguishing between direct and indirect relationships; and deductive

reasoning underlying the cause-and-effect relationships. For this BBN-based conceptual model to be practically feasible for analysing epistemic uncertainties, it was validated empirically through a focus group discussion to confirm whether the right model was built, including all relationships, before introducing it to probability elicitation. After the empirical validation, 15 new relationships between epistemic uncertainties were added to the model while deducting two links between IPMs and epistemic uncertainties. With all these alterations, the cause-and-effect relationships in the model were increased to 58. This empirically validated BBN-based conceptual model (see Chapter 6, Figure 6.16) was used in the final objective (Objective 4 [OBJ.4]) to assess its applicability for analysing information processing for QA within real-world reverse supply chain contexts.

In the BBN-based conceptual information processing model, the impact on QA was reflected through the combined effect of macro-, meso- and micro-level uncertainties in the building dismantling and on-site processing phase and the off-site processing phase. The macro-level uncertainties appeared at the bottom of the model, indicating that they caused the remaining meso- and micro-level uncertainties. Regulatory uncertainties were the root causes that were propagated through incentivising and contractual uncertainties to the meso- and micro-level uncertainties. In accordance with the arrangement of the information processing model, most micro-level uncertainties appeared at the top level of the model as they were influenced by both macro- and meso-level uncertainties. All the micro-level uncertainties were interrelated; thus, they had cause-and-effect relationships. For instance, when considering the micro-level uncertainties of the demolisher, if the ‘as-is’ condition of the building could not be ascertained, the management of contaminated/hazardous substances would undeniably be uncertain for demolishers. Furthermore, if the management of contaminated/ hazardous substances was not properly performed, health and safety would certainly be a concern for demolishers. If all these uncertainties existed, it would be impossible for the workflow to be smooth and effective for demolishers. In the same way, if product descriptions were complicated, the possibility of increasing human errors was higher as were the health and safety concerns and workflow uncertainties of the waste processors. It is worth noting that waste processors’ human errors increased ‘mixed waste received from demolishers’, the meso-level uncertainty of waste processors. ‘Mixed waste received from demolishers’ was an important epistemic uncertainty in the information

processing model for two reasons. Firstly, it bridged the demolisher's and waste processor's epistemic uncertainties in the model. Secondly, among all the epistemic uncertainties, it had the strongest effect on QA in RLSCs of DW, even if it did not directly relate to this performance criterion. As per the arrangement of the information processing model, only workflow uncertainties of the demolisher and waste processor had direct relationships with QA in RLSCs of DW.

In the preliminary causal map (i.e., before applying the principles of the causal mapping approach), most IPMs were positioned so they could be undertaken in response to many epistemic uncertainties of the demolisher and waste processor. However, in the BBN-based conceptual information processing model, as the epistemic uncertainties created cause-and-effect relationships, the effect of an IPM in response to a specific epistemic uncertainty could also be exerted on the remaining epistemic uncertainties linked with the earlier uncertainty. Due to this, all IPMs were positioned at the most appropriate epistemic uncertainties in the model based on the principles of the causal mapping approach. Accordingly, a few IPMs appeared in response to the epistemic uncertainties at the top and bottom of the model on each side of the demolisher and waste processor. Even if the macro-level uncertainties appeared as root causes at the bottom of the model, they stemmed from the external environment due to reasons beyond the control of internal stakeholders in RLSCs. Therefore, only a few IPMs, such as 'rules and programs', 'planning and goal setting' and 'business partnering', could be undertaken in response to these macro-level uncertainties. It is worth noting that these IPMs were impersonal and provided a standard solution for recurrent and/or beyond-control epistemic uncertainties. As the epistemic uncertainties of the model were propagated upwards, the uncertainty level was high in micro-level uncertainties at the top of the model. Therefore, only a few IPMs could be undertaken in response to the epistemic uncertainties at the top of the model. For instance, 'creation of slack resources' was the last resort IPM that could be undertaken in response to health and safety concerns of both demolishers and waste processors. Notably, none of the IPMs were directly attached to workflow uncertainties of demolishers and waste processors, which had direct relationships with QA in RLSCs of DW. In the BBN-based conceptual information processing model, the highest number of IPMs were found in response to meso- and micro-level uncertainties at the intermediate level of the model which were manageable and controllable for demolishers and waste processors. All these IPMs were

mostly personal and used rich media through which situational and prompt information was provided, depending on the issue.

9.2.4 Objective 4: To assess the applicability of the information processing model for QA within real-world reverse supply chain contexts

Objective 4 (OBJ.4) of the research was to assess the applicability of the information processing model for QA within real-world reverse supply chain contexts. The BBN-based conceptual information processing model developed in achieving Objective 3 (OBJ.3) was applied in two real-life cases of RLSCs of DW: one comprising a small and medium-scale demolisher and waste processor and the other comprising a large-scale demolisher and waste processor. However, irrespective of whether the supply chain included small and medium-scale organisations or large-scale organisations, RLSCs of DW were exposed to all 16 epistemic uncertainties in the information processing model for QA. Chapter 7 presents the findings collected to achieve Objective 4.

The current study found that, compared to RLSCs with large-scale organisations, RLSCs with small and medium-scale organisations were more vulnerable to macro-, meso- and micro-level uncertainties for QA (see Chapter 7). Of all the epistemic uncertainties, the RLSCs of DW, irrespective of whether they included large-scale or small and medium-scale organisations, were most susceptible to the waste processor's meso-level uncertainty: 'mixed waste received from demolishers'. It was also found that 'mixed waste received from demolishers' was one of the top five epistemic uncertainties to which the QA was most sensitive in RLSCs of DW. Furthermore, 'workflow uncertainties of the demolisher', 'workflow uncertainties of the waste processor', 'regulatory uncertainties of the demolisher and 'contractual uncertainties from FSC-upstream actors' were the remaining epistemic uncertainties to which QA was most sensitive in RLSCs of DW. Among these top five highly sensitive epistemic uncertainties, two were macro-level uncertainties of demolishers. The study found that of all three levels of epistemic uncertainties, macro-level uncertainties were more important to manage to enhance QA as they were the root causes of the remaining meso- and micro-level uncertainties. As an RLSC of DW was an interrelated process, the operational performance of the building dismantling and on-site processing phase decided the effectiveness of the subsequent off-site waste processing phase. On this

note, the current study found that compared to the waste processor's epistemic uncertainties, the demolisher's epistemic uncertainties were more significant; thus, most appeared in the critical path of epistemic uncertainties influencing QA in RLSCs of DW. In shedding light on this, the current study raised the need to manage the demolisher's epistemic uncertainties, thus minimising the waste processor's uncertainties, ultimately enhancing QA in RLSCs of DW.

The organisations in the RLSCs of DW, whether small and medium scale or large scale, were more effective in reducing uncertainties related to the ''as-is' condition of the building' by undertaking appropriate IPMs. Even with the current study identifying 16 IPMs that could respond to epistemic uncertainties, unlike large-scale organisations, the small and medium-scale organisations did do not have the capacity to embrace all of them. It was found that RLSCs with small and medium-scale organisations seldom undertook IPMs, such as business partnering (in response to incentivising uncertainties); forming contracts with demolishers (in response to mixed waste received from demolishers); creation of integrator roles (in response to mixed waste received from demolishers); and creation of special reports (in response to product description complexities). No significant increment in the utility value of QA could be observed even if RLSCs of DW with large-scale organisations had undertaken business partnering as an IPM in response to incentivising uncertainties. However, by implementing the other three IPMs, RLSCs with large-scale organisations had significantly enhanced QA in their supply chains. For instance, RLSCs with large-scale organisations had successfully decreased the possibility of receiving mixed waste from demolishers, an epistemic uncertainty that significantly affected QA, through undertaking IPMs such as forming contracts and creating integrator roles, in addition to waste acceptance criteria/gate fees. Thus, the current study revealed to RLSCs with small and medium-scale organisations the importance of undertaking all the IPMs, especially those that could be undertaken in response to the most significant epistemic uncertainties for QA.

9.3 Contributions to Knowledge

According to Phillips and Johnson (2022, p. 77), a PhD research could be original if it complies with, but is not limited, to the following definitions: (i) 'looking at areas that people in the discipline have not previously looked at'; (ii) 'carrying out empirical work

that has not previously been done'; (iii) 'making a synthesis that has not previously been made'; (iv) 'taking a particular technique and applying it in a new area'; (v) 'having a cross-disciplinary approach and using different methodologies'; and (vi) 'adding to knowledge in a way that has not previously been done'. The following subsections explain the contributions of this doctoral research under these definitions.

9.3.1 Looking at areas at which people in the discipline have not previously looked

The body of literature on RLSCs of DW recurrently outlined two issues that confronted the successful adoption of RL in the construction industry. On the one hand, many previous studies highlighted that end-users' negative perceptions of the quality of reprocessed products was a primary issue in RLSCs of DW (Chileshe et al. 2016; Pushpamali et al. 2021; Wijewickrama et al. 2021a). For instance, Pushpamali et al. (2021) expressed the criticism that end-users had a stigma about buying reprocessed products even if they had the expected quality owing to the labels 'reuse' and 'recycle' attached to the products. However, going beyond this negative perception, Chileshe et al. (2016) revealed that the industry has experienced quality issues in reprocessed products in the practical context. On the other hand, another cluster of studies highlighted that RLSCs of DW did not benefit from a well-organised information flow (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b; Wijewickrama, Rameezdeen & Chileshe 2021). Wijewickrama et al. (2021b) found that, in some cases, useful information was trapped in organisations and sometimes could not even be found throughout the supply chain owing to the fragmented, cross-functional and multidisciplinary nature of RLSCs of DW. Consequently, the authors further indicated that information sharing was particularly challenging in complicated supply chains like RLSCs which were attempting to close the materials loops.

Even though diverse causes were responsible for quality issues in reprocessed products, many previous studies highlighted that the root cause was information deficiencies in RLSCs of DW (Chileshe, Jayasinghe & Rameezdeen 2019; Jayasinghe et al. 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021a; Xia & Bakker 2014). For example, Rahimi and Ghezavati (2018) asserted that deficiencies in useful information had created uncertainties in RLSCs of DW which negatively affected efforts to deliver quality output from the supply chain. Furthermore, through SLRs, Jayasinghe, Chileshe

and Rameezdeen (2019) and Wijewickrama et al. (2021a) conceptualised that quality issues in reprocessed products and lack of useful information in RLSCs of DW were interdependent and related. Despite the fact that efforts had been made to reveal the relationship between quality issues in reprocessed products and information deficiencies in RLSCs of DW, none of the previous studies had investigated how these information deficiencies caused quality issues in reprocessed products and what mechanisms could be undertaken to address the lack of information. Thus, this study provided progress towards filling this gap in the literature. On this note, the current study contributed to the knowledge by investigating an area overlooked by previous scholars in the discipline.

9.3.2 Carrying out empirical work that has not previously been done

Wijewickrama et al. (2021a), through an SLR, conceptualised that process, people, policy and technology were crucial aspects of QA in RLSCs of DW. The authors further asserted that an information-centric environment should be available for these aspects that required integration to create a QAS for RLSCs of DW. At the end of their SLR, Wijewickrama et al. (2021a) highlighted the need for an empirical study to establish how this integration should occur in the real-world contexts of RLSCs of DW for QA. In light of this, the results of Objective 1 (OBJ.1) of the current study were the first empirical evidence of how aspects of process, people, policy and technology contributed to creating an information-centric QAS in RLSCs of DW. Accordingly, the current study put forward a new interpretation that the aspects of the QAS, namely, process, people, policy and technology were accountable for creating the information-centric environment needed for them to be integrated for the purpose of QA in RLSCs of DW.

This PhD research was developed based on the theoretical foundation of the OIPT. Even though the OIPT originated with an intra-organisational focus (Galbraith 1973, 1974), it was later extended and applied in dyadic inter-organisational contexts (Bensaou & Venkatraman 1995; Premkumar, Ramamurthy & Saunders 2005). However, these previous studies focused on issues only from the perspectives of the focal organisations of the dyads. Thus, the current study is considered to be the first empirical study conducted through the theoretical lens of OIPT, revealing epistemic

uncertainties and IPMs and focusing on all nodes in the dyadic supply chain of RLSCs of DW.

Previous studies have highlighted that epistemic uncertainties in a supply chain are not in isolation but interact with each other (Flynn, Koufteros & Lu 2016; Peidro, Mula & Poler 2007). Flynn, Koufteros and Lu (2016) posited that supply chains were embedded with macro-, meso- and micro-level uncertainties which formed interactions. The authors further raised the need for a future empirical study to investigate the different types of uncertainties inherent in supply chains and their potential interactions. On this note, to the best of the researcher's understanding, the current study is the first empirical study that has attempted to meet the need in the literature as mentioned above. The findings of Objectives 2, 3 and 4 have provided empirical evidence of the identification of different types of macro-, meso- and micro-level uncertainties for QA, the IPMs that respond to them and their cause-and-effect relationships, based on the context of RLSCs of DW in SA.

9.3.3 Making a synthesis that has not previously been made

Despite many previous studies around the OIPT (e.g., Busse, Meinlschmidt & Foerst 2017; Chang & Tien 2006; Engström & Hedgren 2012; Levander et al. 2011), no study has provided a holistic understanding of information processing for QA, even though it is a significant criterion for operational performance in any supply chain (Nikolaidis 2012). Information processing clarifies that organisations should undertake appropriate IPMs to gather, interpret and synthesise information in responding to IPNs arising from epistemic uncertainties (Galbraith 1973, 1974). Moreover, QA is an information-centric integrated system of process, people, policy and technology (Fox 2013; Wijewickrama et al. 2021a). 'Information processing (i.e., including epistemic uncertainties and IPMs)' and 'QA' are separate concepts as no previous studies have found any relationship. In light of this, the current study synthesised these two concepts based on the findings from achieving all four of the study's objectives. Accordingly, the current study found that the aspects of the QAS act as information processors; thus, they are the sources of both epistemic uncertainties and IPMs. On the one hand, shortcomings in aspects of the QAS create epistemic uncertainties for QA. On the other hand, the same aspects of the QAS are responsible for creating mechanisms that enable information processing to confront epistemic uncertainties for QA in RLSCs of DW. Therefore, by making a

synthesis between ‘information processing’ and ‘QA’ that has not previously been made, this study makes another contribution to the knowledge.

9.3.4 Taking a particular technique and applying it in a new area

According to Phillips and Johnson (2022), applying techniques or approaches in a new area of study is a way of contributing to the knowledge. Accordingly, this study used the BBN modelling technique to provide a holistic understanding of information processing for QA based on the propagation analysis of epistemic uncertainties in RLSCs of DW. The reason to use BBN modelling techniques was primarily that it advocates for effectively visualizing causal relationships between variables in complex settings enabling both forward and back propagation analyses (see Chapter 3, Subsection 3.5.2.3). It further advocates developing multivariate statistical models using subjective and objective data (Qazi et al. 2018). This technique has been widely used in various domains in construction supply chains, such as risk analysis (Guan et al. 2020; Jayasinghe 2019; delay analysis (Balta, Dikmen, & Birgonul, 2021; Wang, Z et al. 2020); and health and safety analysis (Guo et al. 2020). Even though previous studies introduced BBN as an ideal modelling technique to represent the propagation analysis of known epistemic uncertainties (Bullen, Fahey & Kenway 2006; Khanmohammadi 2021; Leong 2018; York & Venkataraman 2010), none of the studies to date have used the technique for that purpose. On this note, the current study contributed to the knowledge by applying the BBN modelling technique in the area of epistemic uncertainty propagation analysis for QA in RLSCs of DW. The reasons for using the BBN technique and the GeNIe software (v. 3.0) in the current study are comprehensively explained in Chapter 3, Subsection 3.5.2.3.

9.3.5 Having a cross-disciplinary approach and using different methodologies

The current study employed an exploratory sequential mixed-methods approach, including both qualitative and quantitative research methods. Accordingly, semi-structured interviews were conducted in the first phase to achieve Objectives 1 and 2. The second and third phases of data collection include structured interviews and a focus group discussion, respectively, through which Objective 3 was accomplished in the current study. In the final phase, two case studies were conducted to achieve Objective 4. The current study was developed entirely based on experts’ views collected

through all four of these phases of data collection. The study involved practitioners as experts representing different disciplinary areas of building dismantling and on-site processing and off-site waste processing in RLSCs of DW. Moreover, in the first data collection phase, the study incorporated experts from state and local government agencies. As mentioned in Chapter 4, Section 4.2, the reason to involve external stakeholders was that they were attentive to the operations in RLSCs and keener than internal stakeholders to raise existing issues in the supply chain. Therefore, the research was developed based on a cross-disciplinary investigation. The contributions from these experts from diverse disciplines advocated reducing the gap between the theory and the practice related to information processing for QA in RLSCs of DW.

9.3.6 Adding to knowledge in a way that has not previously been done

The current study has advanced previous research that used theoretical foundations to explain information deficiencies within RLSCs of DW (van den Berg, Voordijk & Adriaanse 2020) by providing a holistic view of information processing, including all the epistemic uncertainties (i.e., macro-, meso- and micro-level uncertainties) and IPMs of both the demolisher and the waste processor. In addition, the current empirical study suggested some supplements to the literature based on OIPT. That is, the study added five sources of uncertainties based on the context of RLSCs of DW that had not previously been identified: 'regulatory uncertainties'; 'incentivising uncertainties'; 'management of contaminated/hazardous substances'; 'health and safety concerns'; and 'human errors'. Except for regulatory uncertainties, the remainder were new epistemic uncertainties added to the OIPT literature. Previous studies have already conceptualised the term 'regulatory uncertainties' in the context of the manufacturing industry as the decision-maker's inability to predict the actions of regulatory agencies and the state of different attributes and elements of their policy or regulations (Engau & Hoffmann 2009; Hoffmann, Trautmann, & Hamprecht, 2009; Lopez, Sakhel & Busch 2017). However, by expanding this existing view, the current study added a different elucidation to regulatory uncertainties within the context of RLSCs of DW, based on OIPT's arguments. Accordingly, regulatory uncertainties referred to the lack of useful information for internal stakeholders due to the ineffective aggressive influence of government agencies. Furthermore, the study also advanced the literature on OIPT by outlining organisational responses (i.e., IPMs) to the epistemic uncertainties that were

specific tp the context of RLSCs of DW: ‘performance evaluation of sub-contractors’; ‘business partnering’; ‘waste acceptance criteria/gate fees’; and ‘forming contracts’.

9.4 Practical Implications

While contributions to the knowledge have been discussed in Section 9.3, many significant implications for professional practice also could be deduced from the results of the current study. Figure 6.16 (in Chapter 6) depicts the conceptual information processing model for QA developed in the current study, which was statistically validated using the BBN modelling technique with the data collected from real-world contexts of RLSCs of DW. Even without making probabilistic inferences, the structure of the conceptual information processing model itself, as shown in Figure 6.16 (in Chapter 6), is advocated for deriving many implications for practitioners in RLSCs of DW. Previous studies highlighted that a conceptual model was a way of advocating the improvement of the integration of knowledge into policy and practice (Brady et al. 2020; Exworthy 2008). Similarly, the information processing model in the current study provides a holistic understanding of information-centric QA for both internal and external stakeholders of RLSCs of DW. The conceptual information processing model informs internal stakeholders in RLSCs of DW, irrespective of whether they are large scale or small and medium scale, that they are vulnerable to three types of epistemic uncertainties, stemming from the external environment (macro-level), supply chain (meso-level) and internal organisational interactions (micro-level). Accordingly, each of the demolisher and waste processor is susceptible to three macro-level, one meso-level and four micro-level uncertainties. Through following the conceptual information processing model, internal stakeholders could learn that these uncertainties do not independently appear on occasion; instead, they could arise gradually as a chain of uncertainties as they create cause-and-effect relationships. Accordingly, internal stakeholders could understand that the degree of uncertainty of epistemic uncertainties increases from the bottom to the top of the model. For instance, the demolisher should understand that when the ‘as-is’ condition of the building is uncertain, management of contaminated/hazardous substances and/or workers’ health and safety tends to be highly uncertain, subsequently causing workflow uncertainties. The study revealed the important implication that the compounding effect of demolishers’ epistemic uncertainties led to the creation of mixed waste at the end of their process, which ultimately will become a make-or-break uncertainty for waste processors. Notably,

mixed waste received from demolishers was the epistemic uncertainty with the highest probability of occurrence in RLSCs, irrespective of whether they included large-scale or small and medium-scale organisations. With this finding, on the one hand, the study reminds demolishers that they are operating within an integrated supply chain, where their operational inefficacies adversely affect the operational performance of the subsequent phase and, most importantly, the QA of the entire supply chain. On the other hand, the study advises waste processors that the survival of their businesses relies on quality-assured waste from demolishers; thus, they should take appropriate measures to ensure that they deal with the most reliable input customers in the industry.

Furthermore, the conceptual information processing model also sheds light on how internal stakeholders should cope with different epistemic uncertainties. Accordingly, 15 IPMs were found that could be undertaken separately and/or in combination in response to each uncertainty type. As in the information processing model, macro-level uncertainties were the root causes that were propagated and created the remaining meso- and micro-level uncertainties; thus, they should be eradicated to enhance QA in RLSCs of DW. Even though external stakeholders were accountable for minimising the occurrence of macro-level uncertainties at their source (Wijewickrama et al. 2021c), the current study emphasised that internal stakeholders should respond to them internally by undertaking appropriate IPMs. In this regard, internal stakeholders receive insights from the study that IPMs, such as 'rules and programs', 'planning and goal setting' and 'business partnering' which are standard and impersonal and providing solutions for recurrent and/or beyond control problems, are more effective in responding to macro-level uncertainties. Even if a few IPMs could be undertaken in response to the macro-level uncertainties which have occurred for reasons beyond the control of internal stakeholders, it is crucial that they are undertaken as the other IPMs could only become successful when they are in place. The study also indicated that when compounding uncertainties from the macro to meso and micro levels, the IPMs undertaken should be rich in media and personal to provide situational and prompt information. However, as uncertainty levels in the topmost epistemic uncertainties are high, if those uncertainties occur, internal stakeholders are left with the mechanism of only increasing planning targets or reducing performance level to reduce the number of exceptions (i.e., slack resources). Therefore, demolishers and waste processors should undertake appropriate IPMs whenever bottom-level uncertainties occur before they are propagated and create

‘health and safety concerns’ or ‘workflow uncertainties’. Furthermore, the current study indicates to internal stakeholders, especially in RLSCs with small and medium-scale organisations, that if many IPMs are available, undertaking them in combination could successfully respond to some epistemic uncertainties. For instance, there would be a minimal possibility of receiving mixed waste if contracts were formed with demolishers and integrator roles were created, in addition to undertaking the most common IPM, namely, ‘waste acceptance criteria/gate fees’.

After inferencing probabilities using subjective data (i.e., experts’ elicitations), internal stakeholders in RLSCs could use the information processing model in the current study to understand the impact of epistemic uncertainties on QA of the supply chain. This model has been developed using the BBN modelling technique. The propagation analysis of epistemic uncertainties using BBN modelling helps internal stakeholders to update the probabilities whenever they find new data over time. The demolishers and waste processors could use this information processing model to enquire about the prominent epistemic uncertainties that ultimately affect QA in the supply chain. Furthermore, the model also provides information about what IPMs should be undertaken in response to the epistemic uncertainties and, if they are undertaken, their effect on reducing the probability of the occurrence of epistemic uncertainties, thus enhancing QA in RLSCs of DW. As outlined in Chapter 7, internal stakeholders could conduct different types of analyses such as sensitivity analysis, root cause analysis, analysis of IPMs and scenario analyses using the principles of forward and back-propagation to explain the effect and importance of epistemic uncertainties and IPMs on QA in RLSCs of DW.

The current study informs internal stakeholders in RLSCs of DW that the aspects of the QAS, namely, process, people, policy and technology are paramount for creating the information-centric environment needed for them to be integrated and, thus, contributing to QA in RLSCs of DW. With this, the four aspects of process, people, policy and technology are considered information processors for QA in RLSCs of DW. Accordingly, on the one hand, these four aspects are being accused of creating epistemic uncertainties for QA if any of their shortcomings occur. On the other hand, if an epistemic uncertainty is present, these aspects are responsible for creating appropriate mechanisms to process information in response to the IPNs arising from those epistemic uncertainties. On this note, the current study enlightens internal

stakeholders in RLSCs of DW on the importance of having a robust and resilient integrated system of process, people, policy and technology to enhance QA in their supply chains.

The finding of the current research also have implications for policy makers related to RLSCs of DW. Accordingly, policy makers should play an influential role in enhancing QA in the RLSCs of DW. The study found that government agencies were responsible for creating most of the macro-level uncertainties for QA in RLSCs of DW. For instance, regulatory and incentivising uncertainties occur due to lapses and issues in influencing strategies of state and local government agencies. As macro-level uncertainties are the root causes for the remaining meso- and micro-level uncertainties (see Chapter 6, Figure 6.16), they must be managed at their source. However, internal stakeholders have limited capability to manage them as these macro-level uncertainties have stemmed from reasons beyond their control. As a result, they have only undertaken a few IPMs, those which are standard and impersonal, in response to macro-level uncertainties. In this vein, the current study raised the need for policy makers to undertake measures that minimise the possibility of the occurrence of these macro-level uncertainties at their source. Accordingly, in line with Wijewickrama et al. (2021c), the current study highlighted that reforming regulatory instruments and employing effective incentivising mechanisms are significant measures that external stakeholders could undertake to minimise macro-level uncertainties and thereby increase QA in RLSCs of DW.

The study's findings also have implications for FSC actors in the construction industry. The FSC actors should understand that they play crucial roles in QA in RLSCs. Even an influencing strategy that they may not consider significant can provide internal stakeholders with useful information for QA, if not otherwise creating epistemic uncertainties for QA. As the FSC-upstream and -downstream actors influence internal stakeholders by connecting to them at two different points (Wijewickrama et al. 2022), their implications for QA are varied. As FSC-upstream actors initiate RLSCs of DW, they should encourage QA during the building dismantling and on-site processing phase by providing the demolisher with the useful information required for QA via a contract or tender document without pushing to complete the work with reduced time and money targets. On the other hand, the FSC-downstream actors should promote the QA of waste processors' work. The client's preference to use reprocessed products that meet the

specifications is a significant determinant of RL implementation in the construction industry (Pushpamali et al. 2021), probably as they are always seeking to gain maximum quality on a minimum budget (Ghaffar, Burman, & Braimah 2020). Therefore, the FSC-downstream actors should act as promoters for QA during the off-site waste processing phase by developing specifications for products that inform the waste processors of the quality criteria that they should demonstrate in their reprocessed products to meet market demand.

9.5 System integration of the model: A way forward for more practical implementation

Bahill & Dean (1996) defined system integration as 'bringing subsystems together to produce the desired result and ensuring that the subsystems will interact to satisfy the customer's needs' (p. 503). The current study conducted a focus group discussion to qualitatively validate the BBN-based information processing model (see Chapter 6) as the foremost step towards achieving its system integration. Then, with the successful application in two cases (see Chapter 7), it was further confirmed that the BBN-based model developed in the current study desirably provides decision support to the internal stakeholders in the industry as an information processing tool for QA. This model has been constructed to enable a flexible modelling environment for its end users. Therefore, the key success of the practical implementation of the BBN-based information processing model may depend not only on the proposed process but also on the type of organizations in the supply chain and their level of formality in uncertainty management. For this model to be a widely accepted standard tool in the industry, more applications are needed to improve its maturity with a long learning cycle time, an area beyond this research's scope. However, this section provides recommendations from a system integration perspective for practically implementing the information processing model in the industry.

According to Zhang (2017), a BBN-based model could be further extended to a decision-support software incorporating a well-documented and interoperable interface to improve the ease of use of the tool. Yet, this is not coming under the scope of the current study; thus, it could be considered an interesting area for future research. Zhang (2017) mentioned that when the BBN-based model was developed as an industry tool, no pre-knowledge about complicated probability theory was required from the potential

users. In contrast, Leerojanaprapa (2014) posited that training the management team about the probability theory would be valuable for successfully implementing such a tool. Furthermore, due to the flexibility of the Bayesian approach, the management team can integrate the BBN-based model with other techniques such as BIM, the geographic information system (GIS), multi-agent systems and neural networks (Hon et al. 2021). This combination could bring the essence of artificial intelligence and machine learning to the field of RLSC in the construction industry. It also improves the applications of the BBN-based model as the combined application could take advantage of each method, thereby providing powerful tools to tackle complex information processing issues in the RLSCs of DW.

The organizations in RLSCs should implement the BBN-based information processing model as a supporting tool for decision-making in parallel with the other approaches for quality improvements. Generally, every organization implement QA, but at different levels of formality. For instance, some organizations have simple internally developed QA procedures, whereas others, at in more mature level, have sophisticated QASs conforming to international standards. The BBN-based information processing model can enhance information processing at any level of complexity for QA. Herein, the information processing model supports the QM teams to understand what and how much of each epistemic uncertainty they could encounter confronting their QM efforts and appropriate IPMs that could undertake in response to those. Therefore, the QM teams of organizations are considered the best to manage and operationalize the model, avoiding unnecessary duplication of authorities.

The level of epistemic uncertainties encountered by an organization could change from time to time due to the changes in influence from stakeholders or competitors, market forces and continuous business development efforts. Therefore, periodical maintenance and updating of the model is important; if not, it cannot provide useful outcomes to support decision-making effectively (Leerojanaprapa 2014). Herein, it is worth mentioning that when the initial BBN-based model is constructed in a recognized software like GeNie, which was used for the current study, less effort and time are required to modify and revise the model. Leerojanaprapa (2014) further exposed two ways of maintaining the model. First, even if there is no change to the model structure, the probabilities of epistemic uncertainties should be updated with time. This has to be carried out internally at a defined interval by the QM team. Second, if the QM team

finds the organization has been exposed to a new epistemic uncertainty or IPM, the model structure should be reviewed at their consensus. The new model structure could be revised using the same software; however, the CPTs should be updated with new epistemic uncertainties and/or IPMs.

9.6 Limitations and Recommendations for Future Research

Despite several contributions to the knowledge and practice, the current study is not devoid of limitations that need to be addressed.

9.6.1 Context of the study

The current study is limited only to SA with valid justifications, as explained in Chapter 1, Section 1.5 and Chapter 3, Section 3.2. Therefore, future studies could apply the current study's findings to varied geographical contexts while distinguishing the differences in the results based on varied technical, legal and socio-economic attributes between SA and those of the alternate context of interest.

9.6.2 Focus only on the RLSCs of DW

The current study is limited to focusing only on the supply chains that manage DW, which start from the EoL of a building through to the secondary market. However, CDW is generated throughout the life cycle of a project due to the series of activities related to construction, renovation and demolition (Jin et al. 2017). As DW contributes more than 70% of CDW (Chen, K et al. 2021; Wu, H et al. 2016), the current study narrowed its scope by focusing only on RLSCs of DW. Through this limitation, the current study had the opportunity to undertake in-depth research on information processing for QA only in the DW management process in the construction industry. However, the findings of the current study would not be similar for RLSCs of other waste streams, especially if considering the waste generated from construction projects, as the configuration of the supply chain would differ from the one in the current study. Therefore, investigating information processing, including epistemic uncertainties and IPMs, for QA in RLSCs of construction waste would be an interesting future research area.

9.6.3 Uncertainties but not equivocality

As described in Chapter 1, Section 1.5, from the OIPT perspective, Daft and Lengel (1986) stated that organisations should process information to reduce not only epistemic uncertainties but also equivocality. According to the authors, equivocality is a situation where multiple and conflicting interpretations occur due to excess and unnecessary information. However, as highlighted by the body of literature on RLSCs of DW, RLSCs experience information deficiencies (Chileshe, Jayasinghe & Rameezdeen 2019; Rahimi & Ghezavati 2018; Wijewickrama et al. 2021b; Wijewickrama, Rameezdeen & Chileshe 2021; Wu, Z et al. 2022), with the current study limited to focusing on epistemic uncertainties. However, none of the previous studies have attempted to discover whether RLSCs of DW also encounter equivocality for QA; thus, this would be a good direction for future research.

9.6.4 Experts' elicitations but not algorithms

The current study's information processing model for QA is based on the BBN modelling technique, developed through probabilistic elicitations from experts' views. However, previous studies pointed out that BBN-based models could be developed through learning algorithms from historical data, experts' views or both (Badurdeen et al. 2014; Librantz et al. 2020; Luu et al. 2009; Nasir, McCabe & Hartono 2003). The algorithms developed with historical data advocate rapid inference and learning in the BBN-based model by defining many criteria for each variable in the model (Pollino & Henderson 2010), which is a constraint when developing this through experts' elicitations (Nasir, McCabe & Hartono 2003). As RLSCs of DW are a promising but still developing industry in SA, no opportunity was available to obtain historical data for this study from the industry to develop the model based on learning algorithms. On this note, conducting the same study using learning algorithms within developed contexts of RLSCs in China and Hong Kong (Tennakoon, Rameezdeen & Chileshe 2022; Yuan & Shen 2011) where historical data are available, would be an interesting future research area.

References

Abubakar, AM, Elrehail, H, Alatailat, MA & Elçi, A 2019, 'Knowledge management, decision-making style and organizational performance', *Journal of Innovation & Knowledge*, vol. 4, No. 2, pp.104-114.

Abutabenjeh, S & Jaradat, R 2018, 'Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners', *Teaching Public Administration*, vol. 36, no. 3, pp. 237-258.

Adams, KT, Osmani, M, Thorpe, TZ & Thornback, J 2017, 'Circular economy in construction: Current awareness, challenges and enablers', *Proceedings of the Institution of Civil Engineers – Waste and Resource Management,* vol. 170, no. 1, pp. 15-24.

Agburu, JI, Anza, NC & Iyortsuun, AS 2017, 'Effect of outsourcing strategies on the performance of small and medium scale enterprises (SMEs)', *Journal of Global Entrepreneurship Research*, vol. 7, no. 1, pp. 1-34.

Aidonis, D 2019, 'Multiobjective mathematical programming model for the optimization of end-of-life buildings' deconstruction and demolition processes', *Sustainability*, vol. 11, no. 5, pp. 1-11.

Ajayi, SO & Oyedele, LO 2018, 'Waste-efficient materials procurement for construction projects: A structural equation modelling of critical success factors', *Waste Management,* vol. 75, May, pp. 60-69.

Ajayi, SO, Oyedele, LO, Akinade, OO, Bilal, M, Owolabi, HA, Alaka, HA & Kadiri, KO 2016, 'Reducing waste to landfill: A need for cultural change in the UK construction industry', *Journal of Building Engineering,* vol. 5, pp. 185-93.

Akanbi, L, Oyedele, L, Delgado, JMD, Bilal, M, Akinade, O, Ajayi, A & Mohammed-Yakub, N 2019, 'Reusability analytics tool for end-of-life assessment of building materials in a circular economy', *World Journal of Science, Technology and Sustainable Development*, vol. 16, no. 1, pp. 40-55.

Akinade, OO, Oyedele, LO, Ajayi, SO, Bilal, M, Alaka, HA, Owolabi, HA, Bello, SA, Jaiyeoba, BE & Kadiri, KO 2017, 'Design for Deconstruction (DfD): Critical success factors for diverting end-of-life waste from landfills', *Waste Management*, vol. 60, pp. 3-13.

Akinade, OO, Oyedele, LO, Oyedele, A, Davila Delgado, JM, Bilal, M, Akanbi, L, Ajayi, A & Owolabi, H 2020, 'Design for deconstruction using a circular economy approach: Barriers and strategies for improvement', *Production Planning & Control*, vol. 31, no. 10, pp. 829-840.

Aldowah, H, Al-Samarraie, H, Alzahrani, AI & Alalwan, N 2020, 'Factors affecting student dropout in MOOCs: A cause and effect decision-making model', *Journal of Computing in Higher Education*, vol. 32, no. 2, pp. 429-454.

Alshenqeeti, H 2014 'Interviewing as a data collection method: A critical review', *English Linguistics Research*, vol. 3, no. 1, pp. 39-45.

Alsheyab, MAT 2022, 'Recycling of construction and demolition waste and its impact on climate change and sustainable development', *International Journal of Environmental Science and Technology*, vol. 19, pp. 2129-2138.

Aminu, LA & Lee, A 2018, 'A comparative study of sustainable end-of-life management in automobile and construction industry: A case of Kano City, Nigeria', *Journal of Civil Engineering and Construction Technology*, vol. 9, no. 4, pp. 40-48.

Anastasiades, K, Michels, S, Van Wuytswinkel, H, Blom, J & Audenaert, A 2022, 'Barriers for the circular reuse of steel in the Belgian construction sector: An industry-wide perspective', *Proceedings of the Institution of Civil Engineers–Management, Procurement and Law*, pp. 1-14.

Apostolopoulos, N & Liargovas, P 2016, 'Regional parameters and solar energy enterprises: Purposive sampling and group AHP approach', *International Journal of Energy Sector Management*, vol. 10, no. 1, pp. 19-37.

Arshad, H, Qasim, M, Thaheem, MJ & Gabriel, HF 2017, 'Quantification of material wastage in construction industry of Pakistan: An analytical relationship between

building types and waste generation', *Journal of Construction in Developing Countries*, vol. 22, no. 2, pp. 19-34.

Aschehoug, SH, Boks, C & Støren, S 2012, 'Environmental information from stakeholders supporting product development,' *Journal of Cleaner Production*, vol. 31, pp. 1-13.

Ashby, A 2018, 'Developing closed loop supply chains for environmental sustainability: Insights from a UK clothing case study', *Journal of Manufacturing Technology Management*, vol. 29, no. 4, pp. 699-722.

Ashrafi, M, Davoudpour, H & Khodakarami, V 2015, 'Risk assessment of wind turbines: Transition from pure mechanistic paradigm to modern complexity paradigm', *Renewable and Sustainable Energy Reviews*, vol. 51, pp. 347-355.

Assarroudi, A, Heshmati Nabavi, F, Armat, MR, Ebadi, A & Vaismoradi, M 2018, 'Directed qualitative content analysis: The description and elaboration of its underpinning methods and data analysis process', *Journal of Research in Nursing*, vol. 23, no. 1, pp. 42-55.

Australian Industry and Skills Committee (AISC) 2022, *Construction*, Department of Education, Australian Government, viewed 06 June 2022, <https://nationalindustryinsights.aisc.net.au/industries/construction#:~:text=The%20Construction%20industry%20generates%20over,in%20the%20next%20five%20years>.

Babaleye, AO, Kurt, RE & Khan, F 2019, 'Safety analysis of plugging and abandonment of oil and gas wells in uncertain conditions with limited data', *Reliability Engineering & System Safety*, vol. 188, pp. 133-141.

Badurdeen, F, Shuaib, M, Wijekoon, K, Brown, A, Faulkner, W, Amundson, J, Jawahir, IS, Goldsby, TJ, Iyengar, D & Boden, B 2014, 'Quantitative modeling and analysis of supply chain risks using Bayesian theory,' *Journal of Manufacturing Technology Management*. vol. 25, no. 5, pp. 631-654.

Bahill, AT & Dean, FF 1996, 'What is Systems Engineering? A Consensus of Senior Systems Engineers', *Refereed Proceedings of the INCOSE International Symposium*, Detroit, MI, USA, pp. 500-505.

Balasbaneh, AT & Ramli, MZ 2020, 'A comparative life cycle assessment (LCA) of concrete and steel-prefabricated prefinished volumetric construction structures in Malaysia', *Environmental Science and Pollution Research*, vol. 27, no. 34, pp. 43186-43201.

Balta, GK, Dikmen, I & Birgonul, MT 2021, 'Bayesian network based decision support for predicting and mitigating delay risk in TBM tunnel projects,' *Automation in Construction*, vol. 129, p. 103819.

Banihashemi, TA, Fei, J & Chen, PSL 2019, 'Exploring the relationship between reverse logistics and sustainability performance: A literature review,' *Modern Supply Chain Research and Applications*, vol. 1, no. 1, pp. 2-27.

Baporikar, N, Nambira, G & Gomxos, G 2016, 'Exploring factors hindering SMEs' growth: Evidence from Nam[i]bia', *Journal of Science and Technology Policy Management*, vol. 7, no. 2, pp. 190-211.

Barbour, RS & Schostak, J 2005, 'Interviewing and focus groups', *Research Methods in the Social Sciences*, vol. 1, pp. 41-48.

Barros, AI, Dekker, R & Scholten, V 1998, 'A two-level network for recycling sand: A case study', *European Journal of Operational Research*, vol. 110, pp. 199-214.

Bartel, A, Ichniowski, C & Shaw, K 2007, 'How does information technology affect productivity? Plant-level comparisons of product innovation, process improvement, and worker skills', *The Quarterly Journal of Economics*, vol. 122, no. 4, pp. 1721-1758.

Bartnik, R & Park, Y 2018, 'Technological change, information processing and supply chain integration', *Benchmarking: An International Journal*, vol. 25, no. 5, pp. 1279-1301.

Barton, F & Branstetter, IVMD 2007, 'Basics of imaging informatics', *Radiology*, vol. 243, no. 3, pp. 656-723.

Bennett, R 1991, 'How is management research carried out?', in NC Smith & P Dainty (eds), *The Management Research Handbook*, Routledge, New York, pp. 85-103.

Bensaou, M & Venkatraman, N 1995, 'Configurations of interorganizational relationships: A comparison between US and Japanese automakers', *Management Science*, vol. 41, no. 9, pp. 1471-1492.

Bhatnagar, R & Sohal, AS 2005, 'Supply chain competitiveness: Measuring the impact of location factors, uncertainty and manufacturing practices', *Technovation*, vol. 25, no. 5, pp. 443-456.

Bhatti, MI, Awan, HM & Razaq, Z 2014, 'The key performance indicators (KPIs) and their impact on overall organizational performance', *Quality & Quantity*, vol. 48, no. 6, pp. 3127-3143.

Bishop, T 2018, 'How to build quality management in a small to medium enterprise', *Muma Business Review*, vol. 2, no. 4, pp. 43-54.

Blaisi NI 2019, 'Construction and demolition waste management in Saudi Arabia: Current practice and roadmap for sustainable management', *Journal of Cleaner Production*, vol. 221, pp. 167-175.

Bode, C, Wagner, SM, Petersen, KJ & Ellram, LM 2011, 'Understanding responses to supply chain disruptions: Insights from information processing and resource dependence perspectives', *Academy of Management Journal*, vol. 54, no. 4, pp. 833-856.

Brady, SS, Brubaker, L, Fok, CS, Gahagan, S, Lewis, CE, Lewis, J, Lowder, JL, Nodora, J, Stapleton, A, Palmer, MH & Prevention of Lower Urinary Tract Symptoms (PLUS) Research Consortium 2020, 'Development of conceptual models to guide public health research, practice, and policy: Synthesizing traditional and contemporary paradigms,' *Health Promotion Practice*, vol. 21, no. 4, pp. 510-524.

Brandão, R, Edwards, DJ, Hosseini, MR, Silva Melo, AC & Macêdo, AN 2021a, 'Reverse supply chain conceptual model for construction and demolition waste', *Waste Management & Research*, vol. 39, no. 11, pp. 1341-1355.

Brandão, R, Hosseini, MR, Macêdo, AN, Melo, AC & Martek, I 2021b, 'Public administration strategies that stimulate reverse logistics within the construction

industry: A conceptual typology', *Engineering, Construction and Architectural Management*, vol. 29, no. 8, pp. 2924-2949.

Braun, V & Clarke, V 2006, 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77-101.

Bravo, M, De Brito, J, Pontes, J & Evangelista, L 2015a, 'Mechanical performance of concrete made with aggregates from construction and demolition waste recycling plants,' *Journal of Cleaner Production*, vol. 99, pp. 59-74.

Bravo, M, De Brito, J, Pontes, J & Evangelista, L 2015b, 'Durability performance of concrete with recycled aggregates from construction and demolition waste plants', *Construction and Building Materials*, vol. 77, pp. 357-369.

Brittain, S, Ibbett, H, de Lange, E, Dorward, L, Hoyte, S, Marino, A, Milner-Gulland, EJ, Newth, J, Rakotonarivo, S, Veríssimo, D & Lewis, J 2020, 'Ethical considerations when conservation research involves people', *Conservation Biology*, vol. 34, no. 4, pp. 925-933.

Brugnach, M, Dewulf, A, Pahl-Wostl, C & Taillieu, T 2008, 'Toward a relational concept of uncertainty: About knowing too little, knowing too differently, and accepting not to know', *Ecology and Society*, vol. 13, no. 2, pp. 1-17.

Bryman, A 2003, *Quantity and Quality in Social Research*, Routledge, London.

Bryman, A 2006, 'Integrating quantitative and qualitative research: How is it done?' *Qualitative Research*, vol. 6, no. 1, pp. 97-113.

Bullen, E, Fahey, J & Kenway, J 2006, 'The knowledge economy and innovation: Certain uncertainty and the risk economy', *Discourse: Studies in the Cultural Politics of Education*, vol. 27, no. 1, pp. 53-68.

Burgess, RG 1984, *In the Field: An Introduction to Field Research*, Allen & Unwin, London.

Burnard, K & Bhamra, R 2011, 'Organisational resilience: Development of a conceptual framework for organisational responses', *International Journal of Production Research*, vol. 49, no. 18, pp. 5581-5599.

Bushery, J, Reichert, JW & Blass, RF 2003, US Census 2010 Quality Assurance Strategy, *Joint Statistical Meetings–Section on Survey Research Methods*, pp. 749-754.

Busse, C, Meinlschmidt, J & Foerstl, K 2017, 'Managing information processing needs in global supply chains: A prerequisite to sustainable supply chain management', *Journal of Supply Chain Management*, vol. 53, no. 1, pp. 87-113.

Bustillo Revuelta, M 2021, 'Construction and demolition waste', in *Construction Materials*, pp. 565-585.

Butera, S, Christensen, TH & Astrup, TF 2014, 'Composition and leaching of construction and demolition waste: Inorganic elements and organic compounds', *Journal of Hazardous Materials*, vol. 276, pp. 302-311.

Caldera, S, Ryley, T & Zatyko, N 2020, 'Enablers and barriers for creating a marketplace for construction and demolition waste: A systematic literature review', *Sustainability*, vol. 12, no. 23, p. 9931.

Calvo N, Varela-Candamio L & Novo-Corti I 2014, 'A dynamic model for construction and demolition (C&D) waste management in Spain: Driving policies based on economic incentives and tax penalties', *Sustainability,* vol. 6, no. 1. pp. 416-435.

Carter, CR & Ellram, LM 1998, 'Reverse logistics: A review of the literature and framework for future investigation', *Journal of Business Logistics*, vol. 19, no. 1, pp. 85-102.

Casadesús, M & de Castro, R 2005, 'How improving quality improves supply chain management: Empirical study', *The TQM Magazine*, vol. 17, no. 4, pp. 345-357.

Cha, HS, Kim, KH & Kim, CK 2012, 'Case study on selective demolition method for refurbishing deteriorated residential apartments', *Journal of Construction Engineering and Management,* vol. 138, no. 2, pp. 294-303.

Chalabi, M, Mohamed, H & Mukhtar, M 2021, 'The validation of an e-voting adoption model using focus group', *Refereed Proceedings of the 2021 International Conference on Electrical Engineering and Informatics (ICEEI),* IEEE, pp. 1-6.

Chang, AS & Tien, CC 2006, 'Quantifying uncertainty and equivocality in engineering projects', *Construction Management and Economics*, vol. 2, no. 2, pp. 171-184.

Chartered Institute of Building (CIOB) 2020, *Real Face of Construction 2020*, viewed 08 June 2022, < https://www.globalconstructionreview.com/actual-uk-construction-gdp-almost-double-official/#:~:text=The%20report%2C%20Real%20Face%20of,employment%20for%202.3%20million%20people>.

Chen, K, Wang, J, Yu, B, Wu, H & Zhang, J 2021, 'Critical evaluation of construction and demolition waste and associated environmental impacts: A scientometric analysis', *Journal of Cleaner Production*, vol. 287, p. 125071.

Chen, Z, Xu, J, Chen, Y & Lui, EM 2016, 'Recycling and reuse of construction and demolition waste in concrete-filled steel tubes: A review', *Construction and Building Materials*, vol. 126, no. 1, pp. 641-660.

Cheng, JC, & Ma, LY 2013, 'A BIM-based system for demolition and renovation waste estimation and planning', *Waste Management*, vol. 33, pp. 1539-1551.

Chileshe, N, Jayasinghe, RS & Rameezdeen, R 2019, 'Information flow-centric approach for reverse logistics supply chains', *Automation in Construction*, vol. 106, p. 102858.

Chileshe, N, Rameezdeen, R & Hosseini, MR 2016, 'Drivers for adopting reverse logistics in the construction industry: A qualitative study', *Engineering, Construction and Architectural Management*, vol. 23, no. 2, pp. 134-157.

Chileshe, N, Rameezdeen, R, Hosseini, MR & Lehmann, S 2015, 'Barriers to implementing reverse logistics in South Australian construction organisations', *Supply Chain Management: An International Journal*, vol. 20, no. 2, pp. 179-204.

Chileshe, N, Rameezdeen, R, Hosseini, MR, Lehmann, S & Udeaja C 2016, 'Analysis of reverse logistics implementation practices by South Australian construction organisations', *International Journal of Operations & Production Management*, vol. 36. no. 3, pp. 332-356.

Chileshe, N, Rameezdeen, R, Hosseini, MR, Martek, I, Li, HX & Panjehbashi-Aghdam, P 2018, 'Factors driving the implementation of reverse logistics: A quantified model for the construction industry', *Waste Management*, vol. 79, pp. 48-57.

Chileshe, N, Rameezdeen, R, Lehmann, S & Hosseini, MR 2014, 'RL implementation among contractors in Australia: Practices and barriers', in AB Raiden & E AboagyeNimo (eds), *Refereed Proceedings of 30th Annual ARCOM Conference*, Portsmouth, UK, 1-3 September 2014, Association of Researchers in Construction Management, pp. 83-92.Chinda, T 2016, 'Investigation of factors affecting a construction waste recycling decision', *Civil Engineering and Environmental Systems*, vol. 33, no. 3, pp. 214-226.

Chinda, T 2017, 'Examination of factors influencing the successful implementation of reverse logistics in the construction industry: Pilot study', *Procedia Engineering*, vol. 182, pp. 99-105.

Chinda, T & Ammarapala, V 2016, 'Decision-making on reverse logistics in the construction industry', *Songklanakarin Journal of Science & Technology*, vol. 38, no. 1, pp. 7-14.

Chinda, T, Engpanyalert, W, Tananoo, A, Chaikong, J & Methawachananont, A 2018, 'Dynamic model for construction and demolition waste recycling in Bangkok, Thailand', *Songklanakarin Journal of Science & Technology*, vol. 40, no. 1, pp. 97-104.

Chinyamurindi, WT & Tsvangirai, FP 2019 'The moderating effect of employee motivation on workplace surveillance and employee engagement amongst employees at the Zimbabwe Revenue Authority', *SA Journal of Human Resource Management*, vol. 17, no. 1, pp. 1-8.

Chung, HW 2002, *Understanding Quality Assurance in Construction: A Practical Guide to ISO 9000 for Contractors*, Routledge, London.

Closs, DJ, Jacobs, MA, Swink, M & Webb, GS 2008, 'Toward a theory of competencies for the management of product complexity: Six case studies', *Journal of Operations Management*, vol. 26, no. 5, pp. 590-610.

Codó, E 2008, ‘Interviews and questionnaires’, in L Wei & M Moyer (eds), *The Blackwell Guide to Research Methods in Bilingualism and Multilingualism*, Blackwell Publishing Ltd, New Jersey, USA, pp. 158-176.

Cohen, L, Manion, L & Morrison, K 2002, *Research Methods in Education*, Routledge, London.

Connell, J, Carlton, J, Grundy, A, Taylor Buck, E, Keetharuth, AD, Ricketts, T, Barkham, M, Robotham, D, Rose, D & Brazier, J 2018, ‘The importance of content and face validity in instrument development: Lessons learnt from service users when developing the Recovering Quality of Life measure (ReQoL)’, *Quality of Life Research*, vol. 27, no. 7, pp. 1893-1902.

Çorbacıoğlu, U & Laan, EA 2013, ‘A quality framework in closed loop supply chains: Opportunities for value creation’, in *Quality Management in Reverse Logistics*, pp. 21-37.

Correia, JMF, de Oliveira Neto, GC, Leite, RR & da Silva, D 2021, ‘Plan to overcome barriers to reverse logistics in construction and demolition waste: Survey of the construction industry’, *Journal of Construction Engineering and Management*, vol. 147, no. 2, p. 04020172.

Cousins, PD, Lawson, B, Petersen, KJ & Handfield, RB 2011, ‘Breakthrough scanning, supplier knowledge exchange, and new product development performance’, *Journal of Product Innovation Management*, vol. 28, no. 6, pp. 930-942.

Crawford, B, Rashif, KMS, Rashidi, A, Sadiq, R & Milani, AS 2020, ‘A Bayesian belief approach to quality control of resin transfer molding process’, *The International Journal of Advanced Manufacturing Technology*, vol. 109, no. 7-8, pp. 1953-1968.

Creswell, JW 2015, ‘Revisiting mixed methods and advancing scientific practices’, in SN Hesse-Biber & RB Johnson (eds), *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry*, Oxford Library of Psychology, UK.

Creswell, JW & Creswell, JD 2017, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, Sage Publications, Thousand Oaks, California, United States.

Cristiano, S, Ghisellini, P, D'Ambrosio, G, Xue, J, Nesticò, A, Gonella, F & Ulgiati, S 2021, 'Construction and demolition waste in the Metropolitan City of Naples, Italy: State of the art, circular design, and sustainable planning opportunities', *Journal of Cleaner Production*, vol. 293, p. 125856.

Crosby, PB 1979, *Quality is Free: The Art of Making Quality Certain*, New American Library, New York.

Cyert, RM & March, JG 1963, *A Behavioral Theory of the Firm*, Englewood Cliffs, New Jersey.

Cypko, MA, Stoehr, M, Kozniewski, M, Druzdzel, MJ, Dietz, A, Berliner, L & Lemke, HU 2017, 'Validation workflow for a clinical Bayesian network model in multidisciplinary decision making in head and neck oncology treatment', *International Journal of Computer Assisted Radiology and Surgery*, vol. 12, no. 11, pp. 1959-1970.

da Cruz, AG, Cenci, SA & Maia, MCA 2006, 'Quality assurance requirements in produce processing', *Trends in Food Science & Technology*, vol. 17, no. 8, pp. 406-411.

da Paz, DHF, dos Santos Neto, FC, Lafayette, KPV & Malafaya, F 2014, 'Analysis of sustainability indicators on the management construction sites CDW in Recife, Brazil', *Electronic Journal of Geotechnical Engineering*, vol. 19, pp. 1377-1389.

Daft, RL & Lengel, RH 1986, 'Organizational information requirements, media richness and structural design', *Management Science*, vol. 32, no. 5, pp. 554-571.

Dahlbo, H, Bachér, J, Lähtinen, K, Jouttijärvi, T, Suoheimo, P, Mattila, T, Sironen, S, Myllymaa, T & Saramäki, K 2015, 'Construction and demolition waste management – a holistic evaluation of environmental performance', *Journal of Cleaner Production*, vol. 107, pp. 333-341.

Dahlmann, F & Roehrich, JK 2019, 'Sustainable supply chain management and partner engagement to manage climate change information,' *Business Strategy and the Environment*, vol. 28, no. 8, pp. 1632-1647.

Daniel, BK & Harland, T 2017, *Higher Education Research Methodology*, Taylor & Francis, Routledge, UK.

Dasanayaka, CH, Gunarathne, N, Murphy, DF & Nagirikandalage, P 2022, 'Triggers for and barriers to the adoption of environmental management practices by small and medium-sized enterprises: A critical review', *Corporate Social Responsibility and Environmental Management*, vol. 29, pp. 749-764.

de Vasconcelos Gomes, LA, Salerno, MS, Phaal, R & Probert, DR 2018. 'How entrepreneurs manage collective uncertainties in innovation ecosystems', *Technological Forecasting and Social Change*, vol. 128, pp. 164-185.

Debacker, W, Manshoven, S, Peters, M, Ribeiro, A & Weerdt, YD 2017, 'Circular economy and design for change within the built environment: Preparing the transition', *Refereed Proceedings of International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, Netherlands p. 114e117.

Decision Systems Laboratory 2013, '*GeNIe and SMILE*', viewed 21 January 2022, <http://genie.sis.pitt.edu/about.html>.

del Río Merino, M, Gracia, PI & Azevedo, ISW 2010, 'Sustainable construction: Construction and demolition waste reconsidered', *Waste Management & Research*, vol. 28, no. 2, pp. 118-129.

Delis, H, Christaki, K, Healy, B, Loreti, G, Poli, GL, Toroi, P & Meghzifene, A 2017, 'Moving beyond quality control in diagnostic radiology and the role of the clinically qualified medical physicist', *Physica Medica*, vol. 41, pp. 104-108.

Deming, WE 1986, *Out of the Crisis*, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Desai, VM 2018, 'Third-party certifications as an organizational performance liability', *Journal of Management*, vol. 44, no. 8, pp. 3096-3123.

Dey, PK 2010, 'Managing project risk using combined analytic hierarchy process and risk map', *Applied Soft Computing*, vol. 10, no. 4, pp. 990-1000.

Di Maria, F, Bianconi, F, Micale, C, Baglioni, S & Marionni, M 2016, 'Quality assessment for recycling aggregates from construction and demolition waste: An image-based approach for particle size estimation', *Waste Management,* vol. 48, February, pp. 344-352.

Dick, GP 2000, 'ISO 9000 certification benefits, reality or myth?' *The TQM Magazine*, vol. 12, no. 6, pp. 365-371.

Ding, T, Xiao, J & Tam, VW 2016, 'A closed-loop life cycle assessment of recycled aggregate concrete utilization in China', *Waste Management,* vol. 56, October, pp. 367-375.

Divakara, S & Surangi, HAKNS 2021, 'The role of intrapreneurship in the growth of small and medium scale manufacturing enterprises in Sri Lanka', *International Journal of Entrepreneurship,* vol. 25, pp. 1-18.

Dolpanya, K, Land, L & Dick, G 2009, 'Measurements, feedback and empowerment: Critical systems theory as a basis for software process improvement', *Refereed Proceedings of European Conference on Information Systems (ECIS) 2009,* p. 100.

Dong, L & Kouvelis, P 2020, 'Impact of tariffs on global supply chain network configuration: Models, predictions, and future research', *Manufacturing & Service Operations Management,* vol. 22, no. 1, pp. 25-35.

Downe-Wamboldt, B 1992, 'Content analysis: Method, applications, and issues', *Health Care for Women International,* vol. 13, no. 3, pp. 313-321.

Druzdzel, MJ 1999, GeNIe: A development environment for graphical decision-analytic models. *Refereed Proceedings of the 1999 Annual Symposium of the American Medical Informatics Association (AMIA-1999),* Washington, DC, p. 1206.

Durdella, N 2017, *Qualitative Dissertation Methodology: A Guide for Research Design and Methods,* Sage Publications, London.Eden, C, Ackermann, F & Cropper, S 1992, 'The analysis of cause maps', *Journal of Management Studies*, vol. 29, no. 3, pp. 309-324.

Eden, C, Jones, S & Sims, D 1979, *Thinking in Organizations*, Macmillan, London, UK.

Eddy, DM 2006, 'Accuracy versus transparency in pharmacoeconomic modelling', *Pharmacoeconomics*, vol. 24, no. 9, pp. 837-844.

Eisenhardt, KM 1989, 'Building theories from case study research', *Academy of Management Review*, vol. 14, no. 4, pp. 532-550.

Eisenhardt, KM & Graebner, ME 2007, 'Theory building from cases: Opportunities and challenges', *Academy of Management Journal*, vol. 50, no. 1, pp. 25-32.El-Haggar, S & Samaha, A 2019, *Roadmap for Global Sustainability–Rise of the Green Communities*, Springer International Publishing, Berlin/Heidelberg, Germany.

Elo, S & Kyngäs, H 2008, 'The qualitative content analysis process', *Journal of Advanced Nursing*, vol. 62, no. 1, pp. 107-115.

Engau, C & Hoffmann, VH 2009, 'Effects of regulatory uncertainty on corporate strategy—An analysis of firms' responses to uncertainty about post-Kyoto policy', *Environmental Science & Policy*, vol. 12, no. 7, pp. 766-777.

Engel, L, Bucholc, J, Mihalopoulos, C, Mulhern, B, Ratcliffe, J, Yates, M & Hanna, L 2020, 'A qualitative exploration of the content and face validity of preference-based measures within the context of dementia', *Health and Quality of Life Outcomes*, vol. 18, no. 1, pp. 1-19.

Engström, S & Hedgren, E 2012, 'Sustaining inertia? Construction clients' decision-making and information-processing approach to industrialized building innovations', *Construction Innovation*, vol. 12, no. 4, pp. 393-413.

Eppich, WJ, Gormley, GJ & Teunissen, PW 2019, 'In-depth interviews', *Healthcare Simulation Research*, Springer, Cham, pp. 85-91.

Eurostat 2020, *Waste Statistics 2020*, viewed 15 November 2021, <https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Waste_generation_excluding_major_mineral_waste>.

Exworthy, M 2008, 'Policy to tackle the social determinants of health: Using conceptual models to understand the policy process', *Health Policy and Planning*, vol. 23, no. 5, pp. 318-327.

Feger, ALR 2014, 'Creating cross-functional strategic consensus in manufacturing facilities', *International Journal of Operations & Production Management*, vol. 34, no. 7, pp. 941-970.

Fellows, R & Liu, A 2015, *Research Methods of Construction*, 4th edn, Wiley Blackwell, UK.

Feng, P, Chang, H, Xu, G, Liu, Q, Jin, Z & Liu, J 2019, 'Feasibility of utilizing recycled aggregate concrete for revetment construction of the lower Yellow River', *Materials*, vol. 12. no. 24, p. 4237.

Feng, X, Jiang, J & Wang, W 2020, 'Gas pipeline failure evaluation method based on a Noisy-OR gate Bayesian network', *Journal of Loss Prevention in the Process Industries*, vol. 66, p. 104175.

Ferdous, W, Manalo, A, Siddique, R, Mendis, P, Zhuge, Y, Wong, HS, Lokuge, W, Aravinthan, T & Schubel, P 2021, 'Recycling of landfill wastes (tyres, plastics and glass) in construction–A review on global waste generation, performance, application and future opportunities', *Resources, Conservation and Recycling*, vol. 173, p. 105745.

Fernhaber, SA & Patel, PC 2012, 'How do young firms manage product portfolio complexity? The role of absorptive capacity and ambidexterity', *Strategic Management Journal*, vol. 33, no. 13, pp. 1516-1539.

Filippi, G &Vasile, M 2021, 'A multi layer evidence network model for the design process of space systems under epistemic uncertainty', in *Advances in Evolutionary and Deterministic Methods for Design, Optimization and Control in Engineering and Sciences*, Springer, Cham, pp. 227-243.

Fischer, E & Guzel, GT 2022, 'The case for qualitative research', *Journal of Consumer Psychology*, pp. 1-14.

Flynn, BB & Flynn, EJ 1999, 'Information-processing alternatives for coping with manufacturing environment complexity', *Decision Sciences*, vol. 30, no. 4, pp. 1021-1052.

Flynn, BB, Koufteros, X & Lu, G 2016, 'On theory in supply chain uncertainty and its implications for supply chain integration', *Journal of Supply Chain Management*, vol. 52, no. 3, pp. 3-27.

Foerstl, K, Meinlschmidt, J & Busse, C 2018, 'It's a match! Choosing information processing mechanisms to address sustainability-related uncertainty in sustainable supply management', *Journal of Purchasing and Supply Management*, vol. 24, no. 3, pp. 204-217.

Forster, PW 2000, 'The performance impact of interorganizational information systems: An empirical study on on-time performance in US air cargo', PhD thesis, University of California Irvine.

Forsythe, P & Fini, AAF 2018, 'Quantifying demolition fitout waste from Australian office buildings', *Facilities*, vol. 36, no. 11/12, pp. 600-617.

Forward Business Information Co. Ltd 2020, *Report of Market Research and Investment Forecast Analysis on China Construction and Demolition Waste Disposal Industry (2020–2025)*, Forward Business Information Co. Ltd., Shenzhen, China.

Foster, ST 2012, *Managing Quality–Integrating the Supply Chain*, Pearson, Harlow, UK.

Fox, MJ 2013, *Quality Assurance Management*, Springer, New York, USA.

Fox, N 2006, *Using Interviews in a Research Project*. National Institute for Health and Care Research (NIHR) Research Design Service (RDS) for the East Midlands/ Yorkshire & the Humber.

Frechette, J, Bitzas, V, Aubry, M, Kilpatrick, K & Lavoie-Tremblay, M 2020, 'Capturing lived experience: Methodological considerations for interpretive phenomenological inquiry', *International Journal of Qualitative Methods*, vol. 19, pp. 1-12.

Frooman, J & Murrell, AJ 2005, 'Stakeholder influence strategies: The roles of structural and demographic determinants', *Business & Society*, vol. 44, no. 1, pp. 3-31.

Galbraith, JR 1973, *Designing Complex Organizations*, Addison-Wesley, Reading, UK.

Galbraith, JR 1974, 'Organization design: An information processing view', *Interfaces*, vol. 4, no. 3, pp. 28-36.

Galbraith, JR 1977, *Organization Design*, Prentice Hall, USA.

Gales, L, Porter, P & Mansour-Cole, D 1992, 'Innovation project technology, information processing and performance: A test of the Daft and Lengel conceptualization', *Journal of Engineering and Technology Management*, vol. 9, no. 3-4, pp. 303-338.

Gan, VJL & Cheng, JCP 2015, 'Formulation and analysis of dynamic supply chain of backfill in construction waste management using agent-based modeling', *Advanced Engineering Informatics*, vol. 29, no. 4, pp. 878-888.

Garvey, MD, Carnovale, S & Yeniyurt, S 2015, 'An analytical framework for supply network risk propagation: A Bayesian network approach', *European Journal of Operational Research*, vol. 243, no. 2, pp. 618-627.

Gattiker, TF 2007, 'Enterprise resource planning (ERP) systems and the manufacturing–marketing interface: an information-processing theory view', *International Journal of Production Research*, vol. 45, no. 13, pp. 2895-2917.

Gattiker, TF & Goodhue, DL 2005, 'What happens after ERP implementation: Understanding the impact of interdependence and differentiation on plant-level outcomes', *MIS Quarterly*, vol. 29, no. 3, pp. 559-585.Ge, XJ, Livesey, P, Wang, J, Huang, S, He, X & Zhang, C 2017, 'Deconstruction waste management through 3D reconstruction and BIM: A case study', *Visualization in Engineering*, vol. 5, no. 1, pp. 1-15.

Ghadge, A, Fang, X, Dani, S & Antony, J 2017, 'Supply chain risk assessment approach for process quality risks', *International Journal of Quality & Reliability Management*, vol. 34, no. 7, pp. 940-954.

Ghaffar, SH, Burman, M & Braimah, N 2020, 'Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery', *Journal of Cleaner Production*, vol. 244, p. 118710.

Ghauri, P 2004. 'Designing and conducting case studies in international business research', *Handbook of Qualitative Research Methods for International Business*, vol. 1, no. 1, pp. 109-124.

Ghosal, V & Ye, Y 2015, 'Uncertainty and the employment dynamics of small and large businesses', *Small Business Economics*, vol. 44, no. 3, pp. 529-558.

Giabbanelli, PJ, Rice, KL, Galgoczy, MC, Nataraj, N, Brown, MM, Harper, CR, Nguyen, MD & Foy, R 2022, 'Pathways to suicide or collections of vicious cycles? Understanding the complexity of suicide through causal mapping', *Social Network Analysis and Mining*, vol. 12, no. 1, pp. 1-21.

Gilfillan, G 2018, 'Characteristics and use of casual employees in Australia', Statistics and Mapping Section, Parliamentary Services, Canberra, Australia.

Gilmore, JL 1974, 'Product conformance cost', *Quality Progress*, vol. 7, no. 5, pp. 16-19.

Ginga, CP, Ongpeng, JMC, Daly, M & Klarissa, M 2020, 'Circular economy on construction and demolition waste: A literature review on material recovery and production', *Materials*, vol. 13, no. 13, p. 2970.

Goldstein, M 2006, 'Subjective Bayesian analysis: Principles and practice', *Bayesian Analysis*, vol. 1, no. 3, pp. 403-420.

Goldstone, J 1998, 'The role of quality assurance versus continuous quality improvement', *Journal of Vascular Surgery*, vol. 28, no. 2, pp. 378-380.

Gołębiewski, B, Trajer, J, Jaros, M & Winiczenko, R 2013, 'Modelling of the location of vehicle recycling facilities: A case study in Poland', *Resources, Conservation and Recycling*, vol. 80, pp. 10-20.

Gorard, S & Taylor, C 2004, *Combining Methods in Educational and Social Research*, Open University Press, New York.

Gotzamani, KD & Tsiotras, GD 2001, 'An empirical study of the ISO 9000 standards' contribution towards total quality management', *International Journal of Operations & Production Management*, vol. 21, no. 10, pp. 1326-1342.

Govindan, K, Soleimani, H & Kannan, D 2015, 'Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future', *European Journal of Operational Research*, vol. 240, no. 3, pp. 603-626.

Green Industries South Australia (GISA) 2020, *South Australia's Waste Strategy 2020–2025*, viewed 24 January 2021, <https://www.greenindustries.sa.gov.au/resources/sa-waste-strategy-2020-2025>.

Guan, L, Liu, Q, Abbasi, A & Ryan, MJ 2020, 'Developing a comprehensive risk assessment model based on fuzzy Bayesian belief network (FBBN)', *Journal of Civil Engineering and Management*, vol. 26, no. 7, pp. 614-634.

Guarnieri, P, Cerqueira-Streit, JA & Batista, LC 2020, 'Reverse logistics and the sectoral agreement of packaging industry in Brazil towards a transition to circular economy', *Resources, Conservation and Recycling*, vol. 153, p. 104541.

Guba, EG 1981, 'Criteria for assessing the trustworthiness of naturalistic inquiries', *Educational Communication and Technology*, vol. 29, pp. 75-91.

Gundumogula, M 2020, 'Importance of focus groups in qualitative research', *International Journal of Humanities and Social Science*, vol. 8, no. 11, pp. 299-302.

Guo, S, He, J, Li, J & Tang, B 2020, 'Exploring the impact of unsafe behaviors on building construction accidents using a Bayesian network,' *International Journal of Environmental Research and Public Health*, vol. 17, no. 1, p. 221.

Han, J, Thakur, JK, Corey, R, Christopher, BR, Khatri, D & Acharya, B 2012, 'Assessment of QC/QA technologies for evaluating properties and performance of geosynthetics in roadway systems', *Refereed Proceedings of GeoCongress 2012: State of the Art and Practice in Geotechnical Engineering*, pp. 1350-1359.

Han, Y, Caldwell, ND & Ghadge, A 2020, 'Social network analysis in operations and supply chain management: A review and revised research agenda', *International*

Journal of Operations & Production Management, vol. 40, no. 7/8, pp. 1153-1176.

Harbaugh, R, Maxwell, JW & Roussillon, B 2011, 'Label confusion: The Groucho effect of uncertain standards', *Management Science*, vol. 57, pp. 1512-1527.

Hardicre, J 2014, 'Valid informed consent in research: An introduction', *British Journal of Nursing*, vol. 23, no. 11, pp. 564-567.

Harris, F, McCaffer, R, Baldwin, A & Edum-Fotwe, F 2021, *Modern construction management*, John Wiley & Sons, UK.

Hasan, A 2019, 'Post-adoption use of mobile information and communication technologies in construction projects and its implications for construction productivity', PhD thesis, University of South Australia.

Haußmann, C, Dwivedi, YK, Venkitachalam, K & Williams, MD 2012, 'A summary and review of Galbraith's organizational information processing theory', *Information Systems Theory*, Springer, New York, pp. 71-93.

Henriksen, HJ, Rasmussen, P, Brandt, G, von Bülow, D & Jensen, FV 2007, 'Public participation modelling using Bayesian networks in management of groundwater contamination', *Environmental Modelling & Software*, vol. 22, no. 8, pp. 1101-1113.

Hitchings, R & Latham, A 2020, 'Qualitative methods I: On current conventions in interview research', *Progress in Human Geography*, vol. 44, no. 2, pp. 389-398.

Hoang, NH, Ishigaki, T, Watari, T, Yamada, M & Kawamoto, K 2022, 'Current state of building demolition and potential for selective dismantling in Vietnam', *Waste Management*, vol. 149, pp. 218-227.

Hoffmann, VH, Trautmann, T & Hamprecht, J 2009, 'Regulatory uncertainty: A reason to postpone investments? Not necessarily', *Journal of Management Studies*, vol. 46, no. 7, pp. 1227-1253.

Holden, RR 2010, 'Face validity', in *Corsini Encyclopedia of Psychology*, viewed 26 January 2022, <https://doi.org/10.1002/9780470479216.corpsy0341>.

Hon, CKH, Sun, C, Xia, B, Jimmieson, NL, Way, KA & Wu, PP-Y 2021, 'Applications of Bayesian approaches in construction management research: a systematic review', *Engineering, Construction and Architectural Management*, vol. 29, No. 5, pp. 2153-2182.

Hossain, MU, Wu, Z & Poon, CS 2017, 'Comparative environmental evaluation of construction waste management through different waste sorting systems in Hong Kong', *Waste Management,* vol. 69, Nov, pp. 325-335.

Hosseini, MR, Chileshe, N, Rameezdeen, R & Lehmann, S 2013a, 'The crucial role of design for reverse logistics (DfRL) and harvesting of information (HoI) in reverse logistics systems', *Refereed Proceedings of the 4th International Conference on Engineering, Project, and Production Management (EPPM 2013),* Association of Engineering, Project, and Production Management, pp. 586-599.

Hosseini, MR, Chileshe, N, Rameezdeen, R & Lehmann, S 2013b, 'Sensitizing the concept of RL for construction context', *Refereed Proceedings of International Conference on Civil Engineering Architecture & Urban Sustainable Development*, November 2013, Tabriz, Iran Islamic Azad University, pp. 27-28.

Hosseini, MR, Chileshe, N, Rameezdeen, R & Lehmann, S 2014, 'Reverse logistics for the construction industry: Lessons from the manufacturing context', *International Journal of Construction Engineering and Management,* vol. 3, no. 3, pp. 75-90.

Hosseini, MR, Rameezdeen, R, Chileshe, N & Lehmann, S 2015, 'Reverse logistics in the construction industry', *Waste Management & Research,* vol. 33, no. 6, pp. 499-514.

Hosseini, S & Sarder, MD 2019, 'Development of a Bayesian network model for optimal site selection of electric vehicle charging station', *International Journal of Electrical Power & Energy Systems,* vol. 105, pp. 110-122.

Hsieh, HF & Shannon, SE 2005, 'Three approaches to qualitative content analysis', *Qualitative Health Research,* vol. 15, no. 9, pp. 1277-1288.

Huang, B, Wang, X, Kua, H, Geng, Y, Bleischwitz, R & Ren, J 2018, 'Construction and demolition waste management in China through the 3R principle', *Resources, Conservation and Recycling,* vol. 129, pp. 36-44.

Huang, WL, Lin, DH, Chang, NB & Lin, KS 2002, 'Recycling of construction and demolition waste via a mechanical sorting process', *Resources, Conservation and Recycling*, vol. 37, no. 1, pp. 23-37.

Hugos, MH 2018, *Essentials of supply chain management*, John Wiley & Sons, UK.

Huisman, W & Van Erp, J 2013, 'Opportunities for environmental crime: A test of situational crime prevention theory', *British Journal of Criminology*, vol. 53, no. 6, pp. 1178-1200.

Hult, GTM, Ketchen, DJ & Arrfelt, M 2007, 'Strategic supply chain management: Improving performance through a culture of competitiveness and knowledge development', *Strategic Management Journal*, vol. 28, no. 10, pp. 1035-1052.

Hult, GTM, Ketchen Jr, DJ & Slater, SF 2004, 'Information processing, knowledge development, and strategic supply chain performance', *Academy of Management Journal*, vol. 47, no. 2, pp. 241-253.International Organization for Standardization (ISO) 1994, Q*uality Systems Requirements (ISO 9001:1994)*, ISO, Geneva.

Ireland, RD & Webb, JW 2007, 'A multi-theoretic perspective on trust and power in strategic supply chains', *Journal of Operations Management*, vol. 25, no. 2, pp. 482-497.

Jacobs, RL 2019, 'Work process analysis', in *Work Analysis in the Knowledge Economy*, Palgrave Macmillan, Cham, pp. 145-163.

Jayasinghe, RS 2019, 'Modelling risks in reverse logistics supply chain for demolition waste management: Quality related operational performance', PhD thesis, University of South Australia.

Jayasinghe, RS, Chileshe, N & Rameezdeen, R 2019, 'Information-based quality management in reverse logistics supply chain: A systematic literature review', *Benchmarking: An International Journal*, vol. 26, no. 7, pp. 2146-2187.

Jayasinghe, RS, Rameezdeen, R & Chileshe, N 2019, 'Exploring sustainable post-end-of-life of building operations', *Engineering, Construction and Architectural Management*, vol. 26, no. 4, pp. 689-722.

Jayasinghe, RS, Rameezdeen, R & Chileshe, N 2022, 'Modelling the cause-and-effect relationship risks in reverse logistics supply chains for demolition waste', *Engineering, Construction and Architectural Management*, (ahead-of-print).

Jia, S, Yan, G, Shen, A & Zheng, J 2017, 'Dynamic simulation analysis of a construction and demolition waste management model under penalty and subsidy mechanisms', *Journal of Cleaner Production*, vol. 147, pp. 531-545.

Jiménez-Rivero, A & García-Navarro, J 2016, 'Indicators to measure the management performance of end-of-life gypsum: From deconstruction to production of recycled gypsum', *Waste and Biomass Valorization*, vol. 7, no. 4, pp. 913-927.

Jin, R, Li, B, Zhou, T, Wanatowski, D & Piroozfar, P 2017, 'An empirical study of perceptions towards construction and demolition waste recycling and reuse in China', *Resources, Conservation and Recycling*, vol. 126, pp. 86-98.

Johnson, JL, Adkins, D & Chauvin, S 2020, 'Qualitative research in pharmacy education: A review of the quality indicators of rigor in qualitative research', *American Journal of Pharmaceutical Education [Internet]*, vol. 84, no. 1, pp. 138-146.

Juran, JM 1988, *Juran on Planning for Quality*, Collier Macmillan, USA.

Kadolph, SJ 2007, *Quality Assurance for Textiles and Apparel*, Fairchild Publications, USA.

Kang, K, Besklubova, S, Dai, Y & Zhong, RY 2022, 'Building demolition waste management through smart BIM: A case study in Hong Kong', *Waste Management*, vol. 143, pp. 69-83.

Kanyoma, KE, Agbola, FW & Oloruntoba, R 2021, 'Inhibitors and enablers of supply chain integration across multiple supply chain tiers: Evidence from Malawi', *The International Journal of Logistics Management*, vol. 32, No. 2, pp. 618-649.

Karapetrovic, S & Willborn, W 2000, 'Quality assurance and effectiveness of audit systems', *International Journal of Quality & Reliability Management*, vol. 17, no. 6, pp. 679-703.

Karipidis, P, Athanassiadis, K, Aggelopoulos, S & Giompliakis, E 2009, 'Factors affecting the adoption of quality assurance systems in small food enterprises', *Food Control*, vol. 20, no. 2, pp. 93-98.

Kartam, N, Al-Mutairi, N, Al-Ghusain, I & Al-Humoud, J 2004, 'Environmental management of construction and demolition waste in Kuwait', *Waste Management*, vol. 24, no. 10, pp. 1049-1059.

Kaza, S, Yao, L, Bhada-Tata, P & Woerden, FV 2018, *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*, Urban Development, World Bank, Washington, DC, USA.

Keist, CN 2015, 'Quality control and quality assurance in the apparel industry', in *Garment Manufacturing Technology*, pp. 405-426.

Kembro, J, Näslund, D & Olhager, J 2017, 'Information sharing across multiple supply chain tiers: A Delphi study on antecedents', *International Journal of Production Economics*, vol. 193, pp. 77-86.

Ketchen, DJ & Hult, GTM 2011, 'Building theory about supply chain management: Some tools from the organizational sciences', *Journal of Supply Chain Management*, vol. 47, no. 2, pp. 12-18.

Khanmohammadi, V 2021, 'On the treatment of uncertainty in innovation projects', Master's thesis, University of Stavanger.

Kim, DH, Hettche, M & Spiller, L 2019, 'Incorporating third-party online certifications into a marketing course: The effect of learning style on student responses', *Marketing Education Review*, vol. 29, no. 3, pp. 193-206.

Kitapçi, H & Sezen, B 2007, 'The effects of participation in decision making, individual improvement efforts and training on the quality of the product design process', *Production Planning and Control*, vol. 18, no. 1, pp. 3-8.

Klang, A, Vikman, P-Å & Brattebø, H 2003, 'Sustainable management of demolition waste—An integrated model for the evaluation of environmental, economic and social aspects', *Resources, Conservation and Recycling*, vol. 38, no. 4, pp. 317-334.

Kleemann, F, Lehner, H, Szczypińska, A, Lederer, J & Fellner, J 2017, 'Using change detection data to assess amount and composition of demolition waste from buildings in Vienna', *Resources, Conservation and Recycling,* vol. 123, pp. 37-46.

Kleemann, J, Celio, E & Fürst, C 2017, 'Validation approaches of an expert-based Bayesian belief network in northern Ghana, West Africa', *Ecological Modelling,* vol. 371, pp. 101-118.

Knochenhauer, M, Swaling, VH, Dedda, FD, Hansson, F, Sjökvist, S & Sunnegaerd, K 2013, *Using Bayesian Belief Network (BBN) Modelling for Rapid Source Term Prediction – Final Report,* Nordic Nuclear Safety Research (NKS), Denmark.

Kolus, A, Wells, R & Neumann, P 2018, 'Production quality and human factors engineering: A systematic review and theoretical framework', *Applied Ergonomics,* vol. 73, pp. 55-89.

Kondracki, NL, Wellman, NS & Amundson, DR 2002, 'Content analysis: Review of methods and their applications in nutrition education', *Journal of Nutrition Education and Behavior,* vol. 34, no. 4, pp. 224-230.

Korb, KB & Nicholson, AE 2011, *Bayesian Artificial Intelligence,* 2nd edn, CRC Press.

Korstjens, I & Moser, A 2018, 'Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing', *European Journal of General Practice,* vol. 24, pp. 120-124.

Kourmpanis, B, Papadopoulos, A, Moustakas, K, Stylianou, M, Haralambous, KJ & Loizidou, M 2008, 'Preliminary study for the management of construction and demolition waste', *Waste Management & Research,* vol. 26, no. 3, pp. 267-275.

Kreye, ME 2017, 'Relational uncertainty in service dyads', *International Journal of Operations & Production Management,* vol. 37, no. 3, pp. 363-381.

Kroon, L & Vrijens, G 1995, 'Returnable containers: An example of reverse logistics', *International Journal of Physical Distribution & Logistics Management,* vol. 25, no. 2, pp. 56-68.

Krueger, T, Page, T, Hubacek, K, Smith, L & Hiscock, K 2012, 'The role of expert opinion in environmental modelling', *Environmental Modelling & Software*, vol. 36, pp. 4-18.

Kupakuwana, P 2007, 'A critical analysis of asbestos removal project cost implications', *Cost Engineering*, vol. 49, no. 11, pp. 30-35.

Kyngäs, H 2020, 'Qualitative research and content analysis', in *The Application of Content Analysis in Nursing Science Research*, Springer, Cham, pp. 3-11.

Langseth, H & Portinale, L 2007, 'Bayesian networks in reliability', *Reliability Engineering & System Safety*, vol. 92, no. 1, pp. 92-108.

Lari, A 2002, 'An integrated information system for quality management', *Business Process Management Journal*, vol. 8, no. 2, pp. 169-182.

Leavy, P 2017, *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-based, and Community-based Participatory Research Approaches*, Guilford Publications, New York.

Lee, DC & Bradshaw, GA 1998, *Making Monitoring Work for Managers*, US Forest Service, viewed 05 March 2021, <https://www.researchgate.net/profile/Danny-Lee-6/publication/242187010_Making_Monitoring_Work_for_Managers/links/547c712a0cf2a961e48a2829/Making-Monitoring-Work-for-Managers.pdf>.

Leedy, P & Ormrod, J 2015, *Practical Research: Planning and Design*, Pearson, Essex.

Leerojanaprapa, K 2014, 'A Bayesian belief network modelling process for systemic supply chain risk', PhD thesis, University of Strathclyde, Glasgow, Scotland.

Lemmer, JF & Kanal, LN 2014, 'Qualitative probabilistic networks for planning under uncertainty', *Uncertainty in Artificial Intelligence*, vol. 2, no. 5, p. 197.

Leong, CWK 2018, 'Managing epistemic uncertainties in the underlying models of safety assessment for safety-critical systems', PhD thesis, University of York.

Levander, E, Engström, S, Sardén, Y & Stehn, L 2011, 'Construction clients' ability to manage uncertainty and equivocality', *Construction Management and Economics*, vol. 29, no.7, pp. 753-764.

Li, H, Wu, Y, Cao, D & Wang, Y 2021, 'Organizational mindfulness towards digital transformation as a prerequisite of information processing capability to achieve market agility', *Journal of Business Research*, vol. 122, pp. 700-712.

Levander, E, Engström, S, Sardén, Y & Stehn, L 2011, 'Construction clients' ability to manage uncertainty and equivocality', *Construction Management and Economics*, vol. 29, no.7, pp. 753-764.

Li, H, Wu, Y, Cao, D & Wang, Y 2021, 'Organizational mindfulness towards digital transformation as a prerequisite of information processing capability to achieve market agility', *Journal of Business Research*, vol. 122, pp. 700-712.

Li, S & Lin, B 2006, 'Accessing information sharing and information quality in supply chain management', *Decision Support Systems*, vol. 42, pp. 1641-1656.

Liamputtong, P 2011, 'Focus group methodology: Introduction and history', *Focus Group Methodology: Principle and Practice*, vol. 224, pp. 1-14.

Librantz, AFH, Costa, I, Spinola, MDM, de Oliveira Neto, GC & Zerbinatti, L 2021, 'Risk assessment in software supply chains using the Bayesian method', *International Journal of Production Research*, vol. 59, no. 22, pp. 6758-6775.

Ligita, T, Nurjannah, I, Wicking, K, Harvey, N & Francis, K 2022, 'From textual to visual: the use of concept mapping as an analytical tool in a grounded theory study', *Qualitative Research*, vol. 22, No. 1, pp.126-142.

Lim, JW, Koh, D, Khim, JSG, Le, GV & Takahashi, K 2011, 'Preventive measures to eliminate asbestos-related diseases in Singapore', *Safety and Health at Work*, vol. 2, no. 3, pp. 201-209.

Lin, X, McKenna, B, Ho, CM & Shen, GQ 2019, 'Stakeholders' influence strategies on social responsibility implementation in construction projects', *Journal of Cleaner Production*, vol. 235, pp. 348-358.

Lincoln, YS & Guba, EG 1985, 'Establishing trustworthiness', in *Naturalistic Inquiry*, Sage Publications, Thousand Oaks, California, USA, pp. 289-327.

Liu, Y, Amini-Abyaneh, A, Hertogh, M, Houwing, EJ & Bakker, H 2021, 'Collaborate to learn and learn to collaborate: A case of exploitative learning in the inter-organizational project', *Engineering, Construction and Architectural Management*, vol. 28, no. 3, pp. 809-830.

Lockrey, S, Nguyen, H, Crossin, E & Verghese, K 2016, 'Recycling the construction and demolition waste in Vietnam: Opportunities and challenges in practice', *Journal of Cleaner Production*, vol. 133, pp. 757-766.

Lodi, KP, Smit, HAP & Ayirebi, GK 2014, 'Terrain analysis in the course curricula of the South African Army Engineer Corps', *Scientia Militaria: South African Journal of Military Studies*, vol. 42, no. 1, pp. 102-121.

Loosemore, M 2016, 'Social procurement in UK construction projects', *International Journal of Project Management*, vol. 34, no. 2, pp. 133-144.

Lopez, JMR, Sakhel, A & Busch, T 2017, 'Corporate investments and environmental regulation: The role of regulatory uncertainty, regulation-induced uncertainty, and investment history', *European Management Journal*, vol. 35, no. 1, pp. 91-101.

Lotfi, S, Deja, J, Rem, P, Mróz, R, van Roekel, E & van der Stelt, H 2014, 'Mechanical recycling of EOL concrete into high-grade aggregates', *Resources, Conservation and Recycling*, vol. 87, pp. 117-125.

Lotfi, Z, Mukhtar, M, Sahran, S & Taei Zadeh, A 2013, 'Information sharing in supply chain management', *Proceedia Technology*, vol. 11, pp. 298-304.

Lu, W & Yuan, H 2012, 'Off-site sorting of construction waste: What can we learn from Hong Kong?' *Resources, Conservation and Recycling*, vol. 69, pp. 100-108.

Lundgren, M, Hedlind, M & Kjellberg, T 2015, 'Model-driven process planning and quality assurance', *Procedia CIRP*, vol. 33, pp. 209-214.

Lune, H & Berg, BL 2017, *Qualitative Research Methods for the Social Sciences*, Pearson, USA.

Luu, VT, Kim, S-Y, Tuan, NV & Ogunlana, SO 2009, 'Quantifying schedule risk in construction projects using Bayesian belief networks', *International Journal of Project Management*, vol, 27, pp. 39-50.

Lyberg, L & Stukel, DM 2010, 'Quality assurance and quality control in cross-national comparative studies', in JA Harkness, M Braun, B Edwards, TP Johnson, L Lyberg, PP Mohler, B Pennell & TW Smith (eds), *Survey Methods in Multinational, Multiregional, and Multicultural Contexts*, John Wiley & Sons, Inc., USA, pp. 225-249.

Mah, CM, Fujiwara, T & Ho, CS 2018, 'Environmental impacts of construction and demolition waste management alternatives', *Chemical Engineering Transactions*, vol. 63, pp. 343-348.

Malone, TW, Yates, J & Benjamin, RI 1987, 'Electronic markets and electronic hierarchies', *Communications of the ACM*, vol. 30, no. 6, pp. 484-497.

Man, TW, Lau, T & Chan, KF 2002, 'The competitiveness of small and medium enterprises: A conceptualization with focus on entrepreneurial competencies', *Journal of Business Venturing*, vol. 17, no. 2, pp. 123-142.

Manghani, K 2011, 'Quality assurance: Importance of systems and standard operating procedures', *Perspectives in Clinical Research*, vol. 2, no. 1, p. 34-37.

March, JG & Simon, HA 1958, *Organizations,* Wiley, New York.

Marri, HB, Nebhwani, M & Sohag, RA 2011, 'Study of government support system in SMEs: An empirical investigation', *Mehran University Research Journal of Engineering and Technology*, vol. 30, no. 3, pp. 435-446.

Marshall, C & Rossman, GB 2014, *Designing Qualitative Research*, Sage Publications, London.

Martakis, A & Daneva, M 2013, 'Handling requirements dependencies in agile projects: A focus group with agile software development practitioners', *Refereed Proceedings of IEEE 7th International Conference on Research Challenges in Information Science (RCIS)*, IEEE, pp. 1-11.

Martín-Morales, M, Zamorano, M, Ruiz-Moyano, A & Valverde-Espinosa, I 2011, 'Characterization of recycled aggregates construction and demolition waste for concrete production following the Spanish structural concrete code EHE-08', *Construction and Building Materials*, vol. 25, no. 2, pp. 742-748

Martín-Morales, M, Zamorano, M, Valverde-Palacios, I, Cuenca-Moyano, GM & Sánchez-Roldán, Z 2013, 'Quality control of recycled aggregates (RAs) from construction and demolition waste (CDW)', in *Handbook of Recycled Concrete and Demolition Waste*, pp. 270-303.

Marvasti, A 2010, 'Interviews and interviewing', in P Peterson, E Baker & B McGaw (eds), *International Encyclopedia of Education*, 3rd edn, Elsevier, Netherlands, pp. 424-429.

Mason, J 2006, 'Mixing methods in a qualitatively driven way', *Qualitative Research*, vol. 6, no. 1, pp. 9-25.

Mason, M 2010, 'Sample size and saturation in PhD studies using qualitative interviews', *Forum: Qualitative Social Research*, vol. 11, no. 3, p. 8.

Matta, K, Chen, HG & Tama, J 1998, 'The information requirements of total quality management', *Total Quality Management*, vol. 9, no. 6, pp. 445-461.

Mattick, K, Johnston, J & de la Croix, A 2018, 'How to … write a good research question', *The Clinical Teacher*, vol. 15, no. 2, pp. 104-108.

Maury-Ramírez, A, Illera-Perozo, D & Mesa, JA 2022, 'Circular economy in the construction sector: A case study of Santiago de Cali (Colombia)', *Sustainability*, vol. 14, no. 3, p. 1923.

Maxwell, JA 2021, 'Why qualitative methods are necessary for generalization', *Qualitative Psychology*, vol. 8, pp. 111-118.

Mayring, P 2014, *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*, GESIS–Leibniz Institute for the Social Sciences, Germany.

McGinley, S, Wei, W, Zhang, L & Zheng, Y 2021, 'The state of qualitative research in hospitality: A 5-year review 2014 to 2019', *Cornell Hospitality Quarterly*, vol. 62, pp. 8-20.

McIntosh, MJ & Morse, JM 2015, 'Situating and constructing diversity in semi-structured interviews', *Global Qualitative Nursing Research*, vol. 2, pp. 1-12.

McLaughlin, PM, Sunderland, KM, Beaton, D, Binns, MA, Kwan, D, Levine, B, Orange, JB, Peltsch, AJ, Roberts, AC, Strother, SC & Troyer, AK 2021, 'The quality assurance and quality control protocol for neuropsychological data collection and curation in the Ontario Neurodegenerative Disease Research Initiative (ONDRI) study', *Assessment*, vol. 28, no. 5, pp. 1267-1286.

Meijboom, B, Voordijk, H & Akkermans, H 2007, 'The effect of industry clockspeed on supply chain co-ordination', *Business Process Management Journal*, vol. 13, no. 4, pp. 553-571.

Mercante, IT, Bovea, ND, Ibáñez-Forés V & Arena, AP 2012, 'Life cycle assessment of construction and demolition waste management systems: A Spanish case study', *The International Journal of Life Cycle Assessment*, vol. 17, no. 2, pp. 232-241.

Merriam, SB 1998, *Qualitative Research and Case Study Applications in Education*, Jossey-Bass Publishers, San Francisco.

Mihai, FC 2019, 'Construction and demolition waste in Romania: The route from illegal dumping to building materials', *Sustainability*, vol. 11, no. 11, p. 3179.

Min, S, Zacharia, ZG & Smith, CD 2019, 'Defining supply chain management: In the past, present, and future', *Journal of Business Logistics*, vol. 40, no. 1, pp. 44-55.

Mkhomazi, SS & Iyamu, TA 2013, 'Guide to selecting theory to underpin information systems studies', *Refereed Proceedings of the International Working Conference on Transfer and Diffusion of IT*, Bangalore, India, Springer: Berlin, Germany, pp. 525-537.

Mohan, AM & Reddy, PS 2018, 'Quality assurance through competent people–A study of 'Rashtriya Ispat Nigham Limited, Visakhapatnam'', *International Journal of*

Mechanical and Production Engineering Research and Development, vol. 8, no. 2, pp. 1065-1078.

Morgan, DL & Krueger, RA 1993, 'When to use focus groups and why', *Successful Focus Groups: Advancing the State of the Art*, vol. 1, pp. 3-19.

Moussa, M 2015, 'Monitoring employee behavior through the use of technology and issues of employee privacy in America', *Sage Open*, vol. 5, no. 2, pp. 1-13.

Mulyasa, E, Sauri, RS & Aryani, WD 2019, 'Strengthening of department governance through implementation of an internal quality assurance system', *Refereed Proceedings of 2nd International Conference on Research of Educational Administration and Management (ICREAM 2018)*, Atlantis Press, pp. 207-211.

Munaro, MR, Fischer, AC, Azevedo, NC & Tavares, SF 2019, 'Proposal of a building material passport and its application feasibility to the wood frame constructive system in Brazil', *Refereed Proceedings of IOP Conference Series: Earth and Environmental Science*, IOP Publishing, Bristol, UK, p. 012018.

Mweshi, GK & Sakyi, K 2020, 'Application of sampling methods for the research design', *Archives of Business Review*, vol. 8, no. 11, pp. 180-193.

Naderifar, M, Goli, H & Ghaljaie, F 2017, 'Snowball sampling: A purposeful method of sampling in qualitative research', *Strides in Development of Medical Education*, vol. 14, no. 3, p. e67670.

Nadkarni, S & Shenoy, PP 2004, 'A causal mapping approach to constructing Bayesian networks', *Decision Support Systems*, vol. 38, no. 2, pp. 259-281.

Nagataki, S, Gokce, A, Saeki, T & Hisada, M 2004, 'Assessment of recycling process induced damage sensitivity of recycled concrete aggregates', *Cement and Concrete Research*, vol. 34, no. 6, pp. 965-971.

Namada, JM 2018, 'Organizational learning and competitive advantage', *Handbook of Research on Knowledge Management for Contemporary Business Environments*, IGI Global, Hershey, PA, USA, pp. 86-104.

Nannapaneni, S, Mahadevan, S & Rachuri, S 2016, 'Performance evaluation of a manufacturing process under uncertainty using Bayesian networks', *Journal of Cleaner Production*, vol. 113, pp. 947-959.

Narayanan, S, Jayaraman, V, Luo, Y & Swaminathan, JM 2011, 'The antecedents of process integration in business process outsourcing and its effect on firm performance', *Journal of Operations Management*, vol. 29, no. 1-2, pp. 3-16.

Nasir, D 2000, 'Probabilistic analysis of schedule risk for building construction', Master`s thesis, University of Toronto, Canada.

Nasir, D, McCabe, B & Hartono, L 2003, 'Evaluating risk in construction–schedule model (ERIC–S): Construction schedule risk model', *Journal of Construction Engineering and Management*, vol. 129, no. 5, pp. 518-527.

Nasir, MHA, Genovese, A, Acquaye, AA, Koh, SCL & Yamoah, F 2017, 'Comparing linear and circular supply chains: A case study from the construction industry', *International Journal of Production Economics*, vol. 183, pp. 443-457.

National Health and Medical Research Council 2007, *National Statement on Ethical Conduct in Human Research*, NHMRC, Canberra, viewed 06 April 2022, <http://www.nhmrc.gov.au/publications/synopses/_files/e72.pdf>.

National Waste Report 2020, Department of Agriculture, Water and the Environment, Canberra, Australia, viewed 07 April 2022, <https://www.wmrr.asn.au/common/Uploaded%20files/national-waste-report-2020.pdf?>.

Newaz, MT, Davis, P, Sher, W & Simon, L 2020, 'Factors affecting construction waste management streams in Australia', *International Journal of Construction Management*, pp. 1-9.

Nikmehr, B, Hosseini, MR, Rameezdeen, R, Chileshe, N, Ghoddousi, P & Arashpour, M 2017, 'An integrated model for factors affecting construction and demolition waste management in Iran', *Engineering, Construction and Architectural Management*, vol. 24, no. 6, pp. 1246-1268.

Nikolaidis, Y 2012, *Quality Management in Reverse Logistics: A Broad Look on Quality Issues and Their Interaction with Closed-loop Supply Chains*, Springer Science & Business Media, London.

Noguchi, T, Park, WJ & Kitagaki, R 2015, 'Risk evaluation for recycled aggregate according to deleterious impurity content considering deconstruction scenarios and production methods', *Resources, Conservation and Recycling*, vol. 104, pp. 405-416.

North, J, Blackburn, RA & Curran, J 1998, *The Quality Business: Quality Issues and Smaller Firms*, Routledge, USA.

Ntiamoah, EB, Li, D & Kwamega, M 2016, 'Impact of government and other institutions' support on performance of small and medium enterprises in the agribusiness sector in Ghana', *American Journal of Industrial and Business Management*, vol. 6, no. 5, p. 558.

Nunes, KR, Mahler, CF & Valle, RA 2009, 'Reverse logistics in the Brazilian construction industry', *Journal of Environmental Management*, vol. 90, no. 12, pp. 3717-3720.

Nunoo, EK, Panin, A & Essien, B 2018, 'Environmental health risk assessment of asbestos-containing materials in the brewing industry in Ghana', *Journal of Environmental Research*, vol. 2, no. 2, pp. 3-14.

Nyumba, T, Wilson, K, Derrick, CJ & Mukherjee, N 2018, 'The use of focus group discussion methodology: Insights from two decades of application in conservation', *Methods in Ecology and Evolution*, vol. 9, no. 1, pp. 20-32.

O'Connor, TF, Lawrence, XY & Lee, SL 2016, 'Emerging technology: A key enabler for modernizing pharmaceutical manufacturing and advancing product quality', *International Journal of Pharmaceutics*, vol. 509, pp. 492-498.

O'Grady, T, Minunno, R, Chong, HY & Morrison, GM 2021, 'Design for disassembly, deconstruction and resilience: A circular economy index for the built environment', *Resources, Conservation and Recycling*, vol. 175, p. 105847

Ogunmakinde, OE, Sher, W & Maund, K 2019, 'An assessment of material waste disposal methods in the Nigerian construction industry', *Recycling*, vol. 4, no. 1, p. 13.

Oke, A, Aghimien, D, Aigbavboa, C & Musenga, C 2019, 'Drivers of sustainable construction practices in the Zambian construction industry', *Energy Procedia*, vol. 158, pp. 3246-3252.

Oliver, P 2006, 'Purposive sampling', in V Jupp (ed), *The Sage Dictionary of Social Research Methods*, Sage Publications, London.

Omair, A 2014, 'Sample size estimation and sampling techniques for selecting a representative sample', *Journal of Health Specialties*, vol. 2, no. 4, p. 142.

Onwuegbuzie, AJ & Collins, KM 2007, 'A typology of mixed methods sampling designs in social science research', *Qualitative Report*, vol. 12, no. 2, pp. 281-316.

Opoku, DGJ, Perer, S, Osei-Kyei, R & Rashidi, M 2021, 'Digital twin application in the construction industry: A literature review', *Journal of Building Engineering*, vol. 40, p. 102726.

Oschlag-Michael, N & Datta, S 2015, 'Developing uncertainty and trust constructs', in *Understanding and Managing IT Outsourcing: A Partnership Approach*, Palgrave Macmillan, London, UK, pp. 53-69.

Ossa, A, García, JL & Botero, E 2016, 'Use of recycled construction and demolition waste (CDW) aggregates: A sustainable alternative for the pavement construction industry', *Journal of Cleaner Production*, vol. 135, pp. 379-386.

Ossiannilsson, E 2019, 'Considerations for quality assurance of e-learning provision', *Refereed Proceedings of European Distance and E-Learning Network (EDEN) Conference*, pp. 222-230.

Owolabi, JD, Amusan, LM, Udoh, V, Tunji-Olayeni, PF, Peter, NJ, Omuh, IO & Joshua, O 2014, 'Recycling of some selected building materials in the construction industry: Prospect and challenges', *Science Research*, vol. 2, no. 2, pp. 21-26.

Pang, J, Jin, Y, Feng, H, Yongteng, Z & Zheng, Y 2019, 'Research on manufacturing process quality evaluation model and method of complex product based on IAHP', *Journal of Physics: Conference Series,* vol. 1176, no. 4, p. 042057.

Panidhapu, A, Li, Z, Aliashrafi, A & Peleato, NM 2020, 'Integration of weather conditions for predicting microbial water quality using Bayesian belief networks,' *Water Research*, vol. 170, p. 115349.

Park, J & Tucker, R 2017, 'Overcoming barriers to the reuse of construction waste material in Australia: A review of the literature', *International Journal of Construction Management,* vol. 17, pp. 228-237.

Parraguez, P 2015, 'A networked perspective on the engineering design process: At the intersection of process and organisation architectures', PhD thesis, Technical University of Denmark.

Patel, DJ, Shrivastava, P & Patel, DA 2021, 'Estimation of demolition waste using waste generation rate and logistic flows in Surat, India', in *Integrated Approaches Towards Solid Waste Management*, Springer, Cham, pp. 99-108.

Patel, N 2019, *Practical Project Management for Engineers,* Artech House, Massachusetts.

Peidro, D, Mula, J & Poler, R 2007, 'Supply chain planning under uncertainty: A fuzzy linear programming approach', *Refereed Proceedings of 2007 IEEE International Fuzzy Systems Conference,* IEEE, pp. 1-6.

Peidro, D, Mula, J, Poler, R & Lario, FC 2009, 'Quantitative models for supply chain planning under uncertainty: A review', *The International Journal of Advanced Manufacturing Technology*, vol. 43, no. 3, pp. 400-420.

Phillips, E & Johnson, C 2022, *How to Get a PhD: A Handbook for Students and Their Supervisors*, McGraw-Hill Education, UK.

Pickin, J, Randell, P, Trinh, J & Grant, B 2018, *National Waste Report 2018,* Department of the Environment and Energy, Blue Environment Pty Ltd, Melbourne, Victoria, Australia.

Pickin, J, Wardle, C, O'Farrell, K, Nyunt, P & Donovan, S 2020, *National Waste Report 2020*, Department of Agriculture, Water and the Environment, Melbourne, Victoria, Australia.

Plant, E, Xu, Y & White, GRT 2015, 'Green supply chain management in Chinese electronic manufacturing organisations: An analysis of senior managements' perceptions', *International Journal of Social Ecology and Sustainable Development,* vol. 6, pp. 21-30.

Polit, DF & Beck, CT 2004, *Nursing Research: Principles and Methods,* Lippincott Williams & Wilkins, USA.

Polit, DF & Beck, CT 2010, 'Generalization in quantitative and qualitative research: Myths and strategies', *International Journal of Nursing Studies*, vol. 47, pp. 1451-1458.

Pollino, CA & Henderson, C 2010, 'Bayesian networks: A guide for their application in natural resource management and policy', in *Landscape Logic, Technical Report*, vol. 14. pp. 1-48.

Poon, CS, Yu, ATW & Ng, LH 2001, 'On-site sorting of construction and demolition waste in Hong Kong', *Resources, Conservation and Recycling,* vol. 32, no. 2, pp. 157-172.

Poon, CS, Yu, ATW, See, SC & Cheung, E 2004, 'Minimizing demolition wastes in Hong Kong public housing projects', *Construction Management and Economics,* vol. 22, no. 8, pp. 799-805.

Premkumar, G, Ramamurthy, K & Saunders, CS 2005, 'Information processing view of organizations: An exploratory examination of fit in the context of interorganizational relationships', *Journal of Management Information Systems*, vol. 22, no. 1, pp. 257-294.

Punch, KF 2014, *Introduction to Social Research: Quantitative and Qualitative Approaches,* Sage Publications, London.

Punch, K 2016, *Developing Effective Research Proposals,* Sage Publications, London.Pushpamali, NNC, Agdas, D & Rose, TM 2020, 'Strategic decision

making in construction supply chains: A comparison of reverse logistics strategies', *Frontiers in Built Environment*, vol. 6, p. 593372.

Pushpamali, NNC, Agdas, D, Rose, TM & Yigitcanlar, T 2021, 'Stakeholder perception of reverse logistics practices on supply chain performance', *Business Strategy and the Environment*, vol. 30, no. 1, pp. 60-70.

Qazi, A 2017, 'Supply chain risk management: Exploring an integrated process for managing interdependent risks and risk mitigation strategies', PhD thesis, University of Strathclyde, Glasgow, Scotland.

Qazi, A, Dickson, A, Quigley, J & Gaudenzi, B 2018, 'Supply chain risk network management: A Bayesian belief network and expected utility based approach for managing supply chain risks', *International Journal of Production Economics*, vol. 196, pp. 24-42.

Queheille, E, Taillandier, F & Saiyouri, N 2019, 'Optimization of strategy planning for building deconstruction', *Automation in Construction*, vol. 98, pp. 236-247.

Rafiq, MI, Chryssanthopoulos, MK & Sathananthan, S 2015, 'Bridge condition modelling and prediction using dynamic Bayesian belief networks', *Structure and Infrastructure Engineering*, vol. 11, no. 1, pp. 38-50.

Rahimi, M & Ghezavati, V 2018, 'Sustainable multi-period reverse logistics network design and planning under uncertainty utilizing conditional value at risk (CVaR) for recycling construction and demolition waste', *Journal of Cleaner Production*, vol. 172, pp. 1567-1621.

Rakhmatullaeva, FM & Nurova, GN 2020, 'The importance of trade policy in the economic development of the country', *Economics*, vol. 1, pp. 27-28.

Rameezdeen, R, Chileshe, N, Hosseini, MR & Lehmann, S 2015, 'A qualitative examination of major barriers in implementation of reverse logistics within the South Australian construction sector', *International Journal of Construction Management*, vol. 16, no. 3, pp. 185-196.

Rašković, M, Ragossnig, AM, Kondracki, K & Ragossnig-Angst, M 2020, 'Clean construction and demolition waste material cycles through optimised pre-

demolition waste audit documentation: A review on building material assessment tools', *Waste Management & Research,* vol. 38, No. 9, pp.923-941.

Ratnasabapathy, S, Alashwal, A & Perera, S 2021, 'Exploring the barriers for implementing waste trading practices in the construction industry in Australia', *Built Environment Project and Asset Management,* vol. 11, no. 4, pp. 559-576.

Ravi, V & Shankar, R 2005, 'Analysis of interactions among the barriers of reverse logistics', *Technological Forecasting and Social Change,* vol. 72, no. 8, pp. 1011-1029.

Raweewan, M & Ferrell Jr, WG 2018, 'Information sharing in supply chain collaboration', *Computers & Industrial Engineering,* vol. 126, pp. 269-281.

Rebehy, PCPW, dos Santos Lima, SA, Novi, JC & Salgado Jr, AP 2019, 'Reverse logistics systems in Brazil: Comparative study and interest of multi stakeholders', *Journal of Environmental Management,* vol. 250, p. 109223.

Renshaw, J, Halter, M & Quinn, T 2022, 'Protocol for a scoping review on the development of policy, guidelines and protocols within emergency medical services', *British Paramedic Journal,* vol 6, no. 4, pp. 48-54.

Reynolds, HW & Guest, G 2015, 'Designing research', in *Public Health Research Methods,* Sage Publications, pp. 33-68.

Rezapour, S, Allen, JK & Mistree, F 2015, 'Uncertainty propagation in a supply chain or supply network', *Transportation Research Part E: Logistics and Transportation Review,* vol. 73, pp. 185-206.

Rinsatitnon, N, Dijaroen, W, Limpiwun, T, Suktavee, G & Chinda, T 2018, 'Reverse logistics implementation in the construction industry: Paper waste focus', *Songklanakarin Journal of Science & Technology,* vol. 40, no. 4, pp. 798-805.

Rizos, V, Behrens, A, Van der Gaast, W, Hofman, E, Ioannou, A, Kafyeke, T, Flamos, A, Rinaldi, R, Papadelis, S, Hirschnitz-Garbers, M & Topi, C 2016, 'Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers', *Sustainability,* vol. 8, no. 11, p. 1212.

Robinson, G, Leonard, J & Whittington, T 2021, *Future of Construction: A Global Forecast for Construction to 2030*, Oxford Economics, viewed 08 June 2022, <https://resources.oxfordeconomics.com/hubfs/Africa/Future-of-Construction-Full-Report.pdf>.

Rogers, DS & Tibben-Lembke, RS 1999, *Going Backwards: Reverse Logistics Trends and Practices*, Reverse Logistics Executive Council, Pittsburgh, PA.

Roodman, DM, Lenssen, NK & Peterson, JA 1995, *A Building Revolution: How Ecology and Health Concerns are Transforming Construction*, Worldwatch Institute, Washington.

Rose, C & Stegemann, J 2018, 'From waste management to component management in the construction industry', *Sustainability*, vol. 10, no. 1 pp. 1-21.

Roussat, N, Méhu, J, Abdelghafour, M & Brula, P 2008, 'Leaching behaviour of hazardous demolition waste', *Waste Management*, vol. 28, no. 11, pp. 2032-2040.

Ruiz, LAL, Ramón, XR & Domingo, SG 2020, 'The circular economy in the construction and demolition waste sector–A review and an integrative model approach', *Journal of Cleaner Production*, vol. 248, p. 119238.

Sackett, DL & Wennberg, JE 1997, 'Choosing the best research design for each question: It's time to stop squabbling over the "best" methods', *BMJ*, vol. 315, no. 7123, p. 1636.

Safdar, N, Khalid, R, Ahmed, W & Imran, M 2020, 'Reverse logistics network design of e-waste management under the triple bottom line approach', *Journal of Cleaner Production*, vol. 272, p. 122662.

Saghafi, MD & Teshnizi, ZAH 2011, 'Building deconstruction and material recovery in Iran: An analysis of major determinants', *Procedia Engineering*, vol. 21, pp. 853-63.

Sakib, N, Hossain, NUI, Nur, F, Talluri, S, Jaradat, R & Lawrence, JM 2021, 'An assessment of probabilistic disaster in the oil and gas supply chain leveraging Bayesian belief network', *International Journal of Production Economics*, vol. 235, p. 108107

Saldaña, J 2016, *The Coding Manual for Qualitative Researchers*, Sage Publications, London.

Sandberg, J & Alvesson, M 2011, 'Ways of constructing research questions: Gap-spotting or problematization?' *Organization*, vol. 18, no. 1, pp. 23-44.

Sangiorgi, C, Lantieri, C & Dondi, G 2015, 'Construction and demolition waste recycling: An application for road construction', *International Journal of Pavement Engineering,* vol. 16, no. 6, pp. 530-537.

Sangwan, KS & Choudhary, K 2018, 'Benchmarking manufacturing industries based on green practices', *Benchmarking: An International Journal*, vol. 25, no. 6, pp. 1746-1761.

Saunders, MN, Lewis, P & Thornhill, A 2019, *Research Methods for Business Students EBook*, Pearson Australia Pty Limited, Australia.

Schamne, AN & Nagalli, A 2016, 'Reverse logistics in the construction sector: A literature review', *Electronic Journal of Geotechnical Engineering,* vol. 21, no. 2, pp. 691-702.

Scheepens, AE, Vogtländer, JG & Brezet, JC 2016, 'Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: Making water tourism more sustainable', *Journal of Cleaner Production*, vol. 114, pp. 257-268.

Schoenherr, T & Swink, M 2012, 'Revisiting the arcs of integration: Cross-validations and extensions', *Journal of Operations Management*, vol. 30, no. 1-2, pp. 99-115.

Schötz, S, Butzer, S, Molenda, P, Drews, T & Steinhilper, R 2017, 'An approach towards an adaptive quality assurance', *Procedia CIRP*, vol. 63, pp. 189-194.

Schultmann, F & Sunke, N 2007, 'Organisation of reverse logistics tasks in the construction industry', in *Portugal SB07: Sustainable Construction, Materials and Practices*, pp. 577-584.

Sen, S, Savitskie, K, Mahto, RV, Kumar, S & Khanine, D 2022, 'If it ain't broke, don't fix it? Indian manufacturing SMEs' quest for strategic flexibility', *Journal of Business Research,* vol. 143, pp. 27-35.

Serranti, S, Palmieri, R & Bonifazi, G 2015, 'Hyperspectral imaging applied to demolition waste recycling: Innovative approach for product quality control', *Journal of Electronic Imaging*, vol. 24, no. 4, pp. 043003-1-043003-9.

Shabbir, MS, Asad, M, Faisal, M & Salman, R 2019, 'The relationship between product nature and supply chain strategy: An empirical evidence', *International Journal of Supply Chain Management*, vol. 8, no. 2, pp. 654-658.

Sharma, SK & Kumar, V 2015, 'Optimal selection of third party logistics service providers using quality function deployment and Taguchi loss function', *Benchmarking: An International Journal*, vol. 22, no. 7, pp. 1281-1300.

Sheikh, AHA, Ikram, M, Ahmad, RM, Qadeer, H & Nawaz, M 2019, 'Evaluation of key factors influencing process quality during construction projects in Pakistan', *Grey Systems: Theory and Application*, vol. 9, no. 3, pp. 321-335.

Shooshtarian, S, Caldera, S, Maqsood, T & Ryley, T 2020, 'Using recycled construction and demolition waste products: A review of stakeholders' perceptions, decisions, and motivations', *Recycling*, vol. 5, no. 4, p. 31.

Shooshtarian, S, Maqsood, T, Caldera, S & Ryley, T 2022, 'Transformation towards a circular economy in the Australian construction and demolition waste management system', *Sustainable Production and Consumption*, vol. 30, pp. 89-106.

Shukla, RK 2016, 'Coordination practices in supply chain management: An empirical study of Indian manufacturing firms', *Journal of Management Research*, vol. 16, no. 1, pp. 44-54.

Silverman, D 2000, *Doing Qualitative Research: A Practical Handbook*, Sage Publications, London.

Sim, J & Waterfield, J 2019, 'Focus group methodology: Some ethical challenges', *Quality & Quantity*, vol. 53, no. 6, pp. 3003-3022.

Simms, C & Rogers, B 2006, 'The significance of flexibility in improving return on property investment: The UK perspective', *Facilities*, vol. 24, pp. 106-119.

Sitkin, SB, Sutcliffe, KM & Schroeder, RG 1994, 'Distinguishing control from learning in total quality management: A contingency perspective', *Academy of Management Review*, vol. 19, no. 3, pp. 537-564.

Sluis, S & De Giovanni, P 2016, 'The selection of contracts in supply chains: An empirical analysis', *Journal of Operations Management*, vol. 41, pp. 1-11.

Smith, B 2018, 'Generalizability in qualitative research: Misunderstandings, opportunities and recommendations for the sport and exercise sciences', *Qualitative Research in Sport, Exercise and Health*, vol. 10, pp. 137-149.

Sobotka, A & Czaja, J 2015, 'Analysis of the factors stimulating and conditioning application of reverse logistics in construction', *Procedia Engineering*, vol. 122, pp. 11-18

Sobotka, A, Sagan, J, Baranowska, M & Mazur, E 2017, 'Management of reverse logistics supply chains in construction projects', *Procedia Engineering*, vol. 208, pp. 151-159.

Sopha, BM, Jie, F & Himadhani, M 2021, 'Analysis of the uncertainty sources and SMEs' performance', *Journal of Small Business & Entrepreneurship*, vol. 33, no. 1, pp. 1-27.

Sousa, R & Voss, CA 2008, 'Contingency research in operations management practices', *Journal of Operations Management*, vol. 26, no. 6, pp. 697-713.

Srinivasan, R & Swink, M 2015, 'Leveraging supply chain integration through planning comprehensiveness: An organizational information processing theory perspective', *Decision Sciences*, vol. 46, no. 5, pp. 823-861.

Sroufe, R 2013, 'Quality assurance and consumer electronics recycling', in *Quality Management in Reverse Logistics*, pp. 73-94.

Sroufe, R & Curkovic, S 2008, 'An examination of ISO 9000: 2000 and supply chain quality assurance', *Journal of Operations Management*, vol. 26, no. 4, pp. 503-520.

Statista 2022, *Construction Industry's Share of Gross Domestic Product (GDP) in China from 2011 to 2020*, Statista Inc, Germany.

Steiss, AW 2019, *Strategic management for public and nonprofit organizations*, Routledge, USA.

Stewart, DW, Shamdasani, PN & Rook, DW 2007, 'Analyzing focus group data', in *Focus Groups: Theory and Practice*, 2nd edn, Sage, Thousand Oaks, CA; London.

Subiyakto, AA, Ahlan, AR, Putra, SJ & Kartiwi, M 2015, 'Validation of information system project success model: A focus group study', *SAGE Open*, vol. 5, no. 2, p. 2158244015581650.

Summers, BL 2019, *Effective Processes for Quality Assurance*, CRC Press, Boca Raton, FL, USA.

Summers, D 2003, *Longman Dictionary of Contemporary English*, 4th edn, Pearson Longman, Harlow, UK.

Sun, H, Hui, IK, Tam, AY & Frick, J 2000, 'Employee involvement and quality management', *The TQM Magazine*, vol. 12, no. 5, pp. 350-354.

Swanson, D, Goel, L, Francisco, K & Stock, J 2017, 'Applying theories from other disciplines to logistics and supply chain management: A systematic literature review', *Transportation Journal*, vol. 56, no. 3, pp. 299-356.

Swink, M, Narasimhan, R & Wang, C 2007, 'Managing beyond the factory walls: Effects of four types of strategic integration on manufacturing plant performance', *Journal of Operations Management*, vol. 25, no. 1, pp. 148-164.

Swink, M & Schoenherr, T 2015, 'The effects of cross-functional integration on profitability, process efficiency, and asset productivity', *Journal of Business Logistics*, vol. 36, no. 1, pp. 69-87.Tam, VWY 2009, 'Comparing the implementation of concrete recycling in the Australian and Japanese construction industries', *Journal of Cleaner Production*, vol. 17, no. 7, pp. 688-702.

Tam, VWY, Gao, XF & Tam, CM 2006, 'Quality improvement of recycled aggregate concrete', *Key Engineering Material*, vol. 302-303, pp. 308-313.

Tam, VWY, Tam, CM & Le, KN 2007, 'Removal of cement mortar remains from recycled aggregate using pre-soaking approaches', *Resources, Conservation and Recycling*, vol. 50, no. 1, pp. 82-101.

Tam, VW, Wang, K & Tam, CM 2008, 'Assessing relationships among properties of demolished concrete, recycled aggregate and recycled aggregate concrete using regression analysis', *Journal of Hazardous Materials*, vol. 152, no. 2, pp. 703-714.

Tang, SL, Ahmed, M, Aoieong, RT & Poon, SW 2005, *Construction Quality Management*, Hong Kong University Press, Aberdeen.

Tapia, RS, Daneva, M & van Eck, P, 2007, 'Validating adequacy and suitability of business–IT alignment criteria in an inter-enterprise maturity model 202', *Refereed Proceedings of 11th IEEE International Enterprise Distributed Object Computing Conference (EDOC)*, pp. 202-213.

Tellis, W 1997, 'Application of a case study methodology', *The Qualitative Report*, vol. 3, no. 3, pp. 1-19.

Tennakoon, GA, Rameezdeen, R & Chileshe, N 2022, 'Diverting demolition waste toward secondary markets through integrated reverse logistics supply chains: A systematic literature review', *Waste Management & Research*, vol. 40, no. 3, pp. 274-293.

Thacker, BH, Doebling, SW, Hemez, FM, Anderson, MC, Pepin, JE & Rodriguez, EA 2004, *Concepts of Model Verification and Validation*, Los Alamos National Laboratory.

Thai, V & Jie, F 2018, 'The impact of total quality management and supply chain integration on firm performance of container shipping companies in Singapore', *Asia Pacific Journal of Marketing and Logistics*, vol. 30, no. 3, pp. 605-626.

Thakur, DR 2010, 'Process quality management', *International Journal of Management Prudence*, vol. 1, no. 1, pp. 74-80.

Thatcher, ME & Oliver, JR 2001, 'The impact of technology investments on a firm's production efficiency, product quality, and productivity', *Journal of Management Information Systems,* vol. 18, pp. 17-45.

Thompson, JD 1967, *Organizations in Action,* McGraw-Hill, New York.

Thorne, S 2020, 'The great saturation debate: What the "S word" means and doesn't mean in qualitative research reporting', *Canadian Journal of Nursing Research,* vol. 52, pp. 3-5.

Tischer, A, Besiou, M & Graubner, CA 2013, 'Efficient waste management in construction logistics: A refurbishment case study', *Logistics Research,* vol. 6, no. 4, pp. 159-171.

Tongco, MDC 2007, 'Purposive sampling as a tool for informant selection', *Ethnobotany Research and Applications*, vol. 5, pp. 147-158.

Townsend, T, Tolaymat, T, Leo, K & Jambeck, J 2004, 'Heavy metals in recovered fines from construction and demolition debris recycling facilities in Florida', *Science of the Total Environment,* vol. 332, no. 1-3, pp. 1-11.

Trochim, WM 2006, *The Research Methods Knowledge Base*, 2nd edn, Atomic Dog Publishing, USA.

Trochu, J, Chaabane, A & Ouhimmou, M 2018, 'Reverse logistics network redesign under uncertainty for wood waste in the CRD industry', *Resources, Conservation and Recycling,* vol. 128, pp. 32-47.

Trochu, J, Chaabane, A & Ouhimmou, M 2020, 'A carbon-constrained stochastic model for eco-efficient reverse logistics network design under environmental regulations in the CRD industry', *Journal of Cleaner Production,* vol. 245, p. 118818.

Tushman, ML & Nadler, DA 1978, 'Information processing as an integrating concept in organizational design', *Academy of Management Review*, vol. 3, no. 3, pp. 613-624.

US Environmental Protection Agency 2019, *Facts and Figures about Materials, Waste and Recycling,* viewed 15 November 2021, <https://www.epa.gov/facts-and-

figures-about-materials-waste-and-recycling/construction-anddemolition-debris-material>.

Vaismoradi, M, Jones, J, Turunen, H & Snelgrove, S 2016, 'Theme development in qualitative content analysis and thematic analysis', *Journal of Nursing Education and Practice,* vol. 6, no. 5, pp. 100-110.

Vaismoradi, M, Turunen, H & Bondas, T 2013, 'Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study', *Nursing & Health Sciences,* vol. 15, no. 3, pp. 398-405.

van Assen, MF 2021, 'Training, employee involvement and continuous improvement–The moderating effect of a common improvement method', *Production Planning & Control*, vol. 32, no. 2, pp. 132-144.

van den Berg, M, Voordijk, H & Adriaanse, A 2020, 'Information processing for end-of-life coordination: A multiple-case study', *Construction Innovation*, vol. 20, no. 4, pp. 647-671.

Vaughn, S, Schumm, JS & Sinagub, JM 1996, *Focus Group Interviews in Education and Psychology*, Sage, London.

Vaverková, MD 2019, 'Landfill impacts on the environment', *Geosciences,* vol. 9, no. 10, p. 431.

Vegas, I, Broos, K, Nielsen, P, Lambertz, O & Lisbona, A 2015, 'Upgrading the quality of mixed recycled aggregates from construction and demolition waste by using near-infrared sorting technology', *Construction and Building Materials,* vol. 75, pp. 121-128.

Wagih, AM, El-Karmoty, HZ, Ebid, M & Okba, SH 2013, 'Recycled construction and demolition concrete waste as aggregate for structural concrete', *HBRC Journal,* vol. 9, no. 3, pp. 193-200.

Walker, WE, Harremoës, P, Rotmans, J, van der Sluijs, JP, van Asselt, MBA, Janssen, P & Krayer von Krauss, MP 2003, 'Defining uncertainty: A conceptual basis for uncertainty management in model based decision support', *Integrated Assessment,* vol. 4, pp. 5-17.

Wang, C, Xu, L & Peng, W 2007, 'Conceptual design of remote monitoring and fault diagnosis systems', *Information Systems*, vol. 32, no. 7, pp. 996-1004.

Wang, H, Mastragostino, R & Swartz, CL 2016, 'Flexibility analysis of process supply chain networks', *Computers & Chemical Engineering*, vol. 84, pp. 409-421.

Wang, J, Yu, B, Tam, VW, Li, J & Xu, X 2019, 'Critical factors affecting willingness of design units towards construction waste minimization: An empirical study in Shenzhen, China', *Journal of Cleaner Production*, vol. 221, pp. 526-535.

Wang, P, Fenn, P, Wang, K & Huang, Y 2022, 'A Bayesian belief network predictive model for construction delay avoidance in the UK', *Engineering, Construction and Architectural Management*, vol. 29, no. 5, pp. 2011-2026.

Wang, Z, Li, H & Yang, X 2020, 'Vision-based robotic system for on-site construction and demolition waste sorting and recycling', *Journal of Building Engineering*, vol. 32, p. 101769.

White, P 2017, *Developing Research Questions*, Macmillan International Higher Education, London.

Wibowo, MA, Handayani, NU, Mustikasari, A, Wardani, SA & Tjahjono, B 2022, 'Reverse logistics performance indicators for the construction sector: A building project case', *Sustainability*, vol. 14, no. 2, p. 963.

Wiengarten, F, Ahmed, MU, Longoni, A, Pagell, M & Fynes, B 2017, 'Complexity and the triple bottom line: An information-processing perspective', *International Journal of Operations & Production Management*, vol. 37, no. 9, pp. 1142-1163.

Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021a, 'Quality assurance in reverse logistics supply chain of demolition waste: A systematic literature review', *Waste Management & Research*, vol. 39, no. 1, pp. 3-24.

Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021b, 'Information sharing in reverse logistics supply chain of demolition waste: A systematic literature review', *Journal of Cleaner Production*, vol. 280, p. 124359.

Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021c, 'Minimizing macro-level uncertainties for quality assurance in reverse logistics supply chains of demolition waste', *Sustainability*, vol. 13, no. 23, p. 13069.

Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2022, 'Information-centric influence strategies for quality assurance in reverse logistics supply chains: External stakeholders' perspective', *Benchmarking: An International Journal*, vol. 29, no. 6, pp. 1857-1888.

Wijewickrama, MKCS, Rameezdeen, R & Chileshe, N 2021, 'Information brokerage for circular economy in the construction industry: A systematic literature review', *Journal of Cleaner Production*, vol. 313, p. 127938.

Williams, BD, Roh, J, Tokar, T & Swink, M 2013, 'Leveraging supply chain visibility for responsiveness: The moderating role of internal integration', *Journal of Operations Management*, vol. 31, no. 7-8, pp. 543-554.

Williams, ID, Curran, T, den Boer, E, Pertl, A, Lock, D, Kent, A & Wilding, P 2014, 'Resource efficiency networks in the construction of new buildings', *Refereed Proceedings of the Institution of Civil Engineers – Waste and Resource Management*, vol. 167, no. 4, pp. 139-152.

Williamson, OE 1975, *Markets and Hierarchies: Analysis and Antitrust Implications*, Free Press, New York.

Wilson, J, Mandich, A & Magalhães L 2016, 'Concept mapping: a dynamic, individualized and qualitative method for eliciting meaning', *Qualitative Health Research*, vol. 26, No. 8, pp. 1151–1161.

Winke, P 2017, 'Using focus groups to investigate study abroad theories and practice', *System*, vol. 71, pp. 73-83.

Winwood, J 2019, 'Using interviews', in *Practical Research Methods in Education*, Routledge, UK, pp. 12-21.

Wisdom, J & Creswell, JW 2013, 'Mixed methods: integrating quantitative and qualitative data collection and analysis while studying patient-centered medical home models', University of Nebraska.

Wong, CWY, Lai, KH, Cheng, TCE & Lun, YHV 2015, 'The role of IT-enabled collaborative decision making in inter-organizational information integration to improve customer service performance', *International Journal of Production Economics*, vol. 159, pp. 56-65.

Wong, CY, Boon-itt, S & Wong, CW 2011, 'The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance', *Journal of Operations Management*, vol. 29, no. 6, pp. 604-615.

Wong, CY, Wong, CW & Boon-itt, S 2015, 'Integrating environmental management into supply chains: A systematic literature review and theoretical framework', *International Journal of Physical Distribution & Logistics Management*, vol. 45, pp. 43-68.

Woodward, NB 2012, 'Evaluation, analysis and prediction of geologic structures', *Journal of Structural Geology*, vol. 41, pp. 76-85.

Wu, H, Duan, H, Zheng, L, Wang, J, Niu, Y & Zhang, G 2016, 'Demolition waste generation and recycling potentials in a rapidly developing flagship megacity of South China: Prospective scenarios and implications', *Construction and Building Materials*, vol. 113, pp. 1007-1016.

Wu, H, Zuo, J, Yuan, H, Zillante, G & Wang, J 2020, 'Cross-regional mobility of construction and demolition waste in Australia: An exploratory study', *Resources, Conservation and Recycling*, vol. 156, p. 104710.

Wu, PY, Mjörnell, K, Sandels, C & Mangold, M 2021, 'Machine learning in hazardous building material management: Research status and applications', *Recent Progress in Materials*, vol. 3, no. 2.

Wu, Z, Yang, K, Xue, H, Zuo, J & Li, S 2022, 'Major barriers to information sharing in reverse logistics of construction and demolition waste', *Journal of Cleaner Production*, vol. 350, p. 131331.

Wu, Z, Yu, ATW & Shen, L 2017, 'Investigating the determinants of contractor's construction and demolition waste management behavior in Mainland China', *Waste Management*, vol. 60, Feb, pp. 290-300.

Wu, Z, Yu, AT, Shen, L & Liu, G 2014, 'Quantifying construction and demolition waste: An analytical review', *Waste Management*, vol. 34, no. 9, pp. 1683-1692.

Xanthopoulos, A, Aidonis, D, Vlachos, D & Iakovou, E 2012, 'A planning optimisation framework for construction and demolition waste management', *International Journal of Industrial and Systems Engineering*, vol. 10, no. 3, pp. 257-276.

Xia, H & Bakker, M 2014, 'Reliable classification of moving waste materials with LIBS in concrete recycling', *Talanta*, vol. 120, pp. 239-247.

Xiao, C, Wilhelm, M, van der Vaart, T & Van Donk, DP 2019, 'Inside the buying firm: Exploring responses to paradoxical tensions in sustainable supply chain management', *Journal of Supply Chain Management*, vol. 55, no. 1, pp. 3-20.

Xu, LD 2011, 'Information architecture for supply chain quality management', *International Journal of Production Research*, vol. 49, no. 1, pp. 183-198.

Xu, W & Song, DP 2022, 'Integrated optimisation for production capacity, raw material ordering and production planning under time and quantity uncertainties based on two case studies', *Operational Research*, vol. 22, pp. 2343-2371.

Yeheyis, M, Hewage, K, Alam, MS, Eskicioglu, C & Sadiq, R 2013, 'An overview of construction and demolition waste management in Canada: A lifecycle analysis approach to sustainability', *Clean Technologies and Environmental Policy*, vol. 15, no. 1, pp. 81-91.

Yin, RK 2009, *Case Study Research: Design and Methods*, 4th edn, Sage Publications Inc, Thousand Oaks, CA, USA.

Yin, RK 2014, *Case Study Research Design and Methods*, 5th edn, Sage Publications, Thousand Oaks, CA, USA.

Yin, RK 2017, *Case Study Research and Applications: Design and Methods*, 6th edn, Sage Publications, Thousand Oaks, CA, USA.

Yin, RK 2018, *Case Study Research and Applications*, Sage, London.

Yin, Y, Wang, Y & Lu, Y 2019, 'Antecedents and outcomes of employee empowerment practices: A theoretical extension with empirical evidence', *Human Resource Management Journal,* vol. 29, no. 4, pp. 564-584.

York, JG & Venkataraman, S 2010, 'The entrepreneur–environment nexus: Uncertainty, innovation, and allocation', *Journal of Business Venturing,* vol. 25, no. 5, pp. 449-463

Yu, B, Wang, J, Li, J, Zhang, J, Lai, Y & Xu, X 2019, 'Prediction of large-scale demolition waste generation during urban renewal: A hybrid trilogy method', *Waste Management,* vol. 89, pp. 1-9.

Yu, W, Chavez, R, Jacobs, M, Wong, CY & Yuan, C 2019, 'Environmental scanning, supply chain integration, responsiveness, and operational performance', *International Journal of Operations & Production Management,* vol. 39, no. 5, pp. 787-814.

Yuan, H & Shen, L 2011, 'Trend of the research on construction and demolition waste management', *Waste Management,* vol. 31, no. 4, pp. 670e-679e.Yue, P 2018, 'Environmental pollution hazards of urban construction wastes and related resource recycling measures: A case study in Central China', *Nature Environment and Pollution Technology,* vol. 17, pp. 777-782.

Yuan, H 2017, 'Barriers and countermeasures for managing construction and demolition waste: A case of Shenzhen in China', *Journal of Cleaner Production,* vol. 157, pp. 84-93.

Yuan, H, Wang, Z, Shi, Y & Hao, J 2022, 'A dissipative structure theory-based investigation of a construction and demolition waste minimization system in China', *Journal of Environmental Planning and Management,* vol. 65, No. 3, pp. 514-535.

Zeng, SX, Lou, GX & Tam, VW 2007, 'Managing information flows for quality improvement of projects', *Measuring Business Excellence,* vol. 11, no. 3, pp. 30-40.

Zhang, G 2017, 'Predictive risk modelling with Bayesian network for maritime applications', PhD thesis, Nanyang Technological University, Singapore.

Zhang, LW, Sojobi, AO, Kodur, VKR & Liew, KM 2019, 'Effective utilization and recycling of mixed recycled aggregates for a greener environment', *Journal of Cleaner Production,* vol. 236, p. 117600.

Zhang, Y & Wildemuth, B 2009, 'Thematic content analysis', in *Applications of Social Research Methods to Questions in Information and Library Science,* pp. 308-319.

Zhao, W, Ren, H & Rotter, VS 2011, 'A system dynamics model for evaluating the alternative of type in construction and demolition waste recycling center – The case of Chongqing, China', *Resources, Conservation and Recycling,* vol. 55, no. 11, pp. 933-944.

Zhao, X, Webber, R, Kalutara, P, Browne, W & Pienaar, J 2022, 'Construction and demolition waste management in Australia: A mini-review', *Waste Management & Research,* vol. 40, no. 1, pp. 34-46.

Zheng, L, Wu, H, Zhang, H, Duan, H, Wang, J, Jiang, W, Dong, B, Liu, G, Zuo, J & Song, Q 2017, 'Characterizing the generation and flows of construction and demolition waste in China', *Construction and Building Materials,* vol. 136, pp. 405-413.

Zheng, Y, Zheng, W & Liu, P 2005, 'Research on information integration management of reverse logistics', *Refereed Proceedings of the 7th International Conference on Electronic Commerce*, pp. 851-855.

Zhong, Y & Zhang, Y 2018, 'Research on reverse supply chain problem based on immune algorithm', *Refereed Proceedings of 2018 International Conference on Mechanical, Electronic, Control and Automation Engineering (MECAE 2018),* Atlantis Press, pp. 458-462.

Zhou, H & Benton Jr, WC 2007, 'Supply chain practice and information sharing', *Journal of Operations Management*, vol. 25, no. 6, pp. 1348-1365.

Zoraja, B, Ubavin, D, Stanisavljevic, N, Vujovic, S, Mucenski, V, Hadzistevic, M & Bjelica, M 2022, 'Assessment of asbestos and asbestos waste quantity in the built environment of transition country', *Waste Management & Research,* vol. 40, no. 8, pp. 1285-1296.

Zoraja, B, Živančev, M, Ubavin, D & Nakomčić-Smaragdakis, B 2021, 'Circular economy as possible solution for asbestos burden', *IOP Conference Series: Materials Science and Engineering*, vol. 1163, no. 1, p. 012033.

Appendices

Appendix 1(A): Consent Form: Semi-structured Interviews

University of South Australia

Human Research Ethics Committee
Consent Form

This project has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant please contact the Executive Officer of this Committee, Tel: [redacted]; Email: humanethics@unisa.edu.au.

SECTION 1: CONTACT AND PROJECT DETAILS	
Researcher's Full Name	Madduma Kaluge Chamitha Sanjani Wijewickrama
Contact Details	[redacted]
Supervisor's Name *(students only)*	Associate Professor Nicholas Chileshe Associate Professor Rameez Ramezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather
Contact Details	Associate Professor Nicholas Chileshe [redacted] Associate Professor Rameez Ramezdeen [redacted] Dr Jorge Ochoa Paniagua [redacted] Mr Jim Fairweather [redacted]
Project Number	202659
Project Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

SECTION 2: PARTICIPANT CERTIFICATION

In signing this form, I confirm that:

- I have read the Participant Information Sheet, and the nature and the purpose of the research project have been explained to me. I understand and agree to take part.
- I understand the nature of my involvement in the project.
- I understand that I may not directly benefit from taking part in the project.
- I understand that I can withdraw from the project at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that I will be audiotaped during the study.
- I understand that while information gained during the project may be published, I will not be identified, and my personal results will remain confidential unless required by law.
- I understand that all data collected during the project (including a copy of the audio recordings) will be securely stored in a password-protected computer file for a period of five years only under the accessibility of the researcher and supervisors.

Participant's Signature	*Printed Name*	*Date*

SECTION 3: RESEARCHER CERTIFICATION

I have explained the study to the participant and consider that he/she understand what is involved.

Researcher Signature	*Printed Name*	*Date*

Appendix 1(B): Information Sheet: Semi-structured Interviews



UniSA STEM

PARTICIPANT INFORMATION SHEET – SEMI-STRUCTURED INTERVIEWS

Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste
Project Number	202659
Chief Investigator	Madduma Kaluge Chamitha Sanjani Wijewickrama
Supervisor	Associate Professor Nicholas Chileshe Associate Professor Rameez Rameezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather

Dear Sir/Madam,

I am a HDR student attached to UniSA STEM. You are kindly invited to take part in my PhD research project titled, **"Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste ".**

Purpose of the research

Issues related to the quality of reprocessed products and information deficiency have been found as major hurdles affecting the Reverse Logistics Supply Chains (RLSCs) of demolition waste (DW). Quality assurance (QA) plays a significant role in ensuring the final product's quality. However, the lack of information (epistemic uncertainties) challenges the QA of the RLSCs. Consequently, this research aims to identify and evaluate the epistemic uncertainties involved in RLSCs and the mechanisms that could respond to those. The research intends to develop an information processing model for QA in RLSCs of DW.

The objectives of doing the research

The expectations of this research are summarized in the following objectives.

- To establish how the process, people, policy and technology contribute to the quality assurance in reverse logistics supply chains of demolition waste
- To identify epistemic uncertainties that lead to information processing needs and corresponding information-processing mechanisms for quality assurance in reverse logistics supply chains
- To develop an information processing model for quality assurance in reverse logistics supply chains and empirically validate the model
- To assess the applicability of the information processing model for quality assurance within real reverse supply chain contexts

What you expect to do in the research
If you are willing to participate in this research project, you are kindly requested to express your views and opinions on the questions given in the interview guideline. The interviews will be face-to-face, online, or via the telephone at an agreed time and last for nearly 45-60 minutes. It will be audio-recorded after taking the consent of the participants. There is no right or wrong answer to each question. All the answers will remain confidential, and all the information will be analyzed in general without reference to specific individuals.

Benefits to the participant
This research will ultimately improve the QA of RLSCs in construction by making the information as the supporting tool. In the end, the participant will also be given the opportunity to receive a summary of the collated results upon request, which may indirectly support advancing reprocessed products' popularity in the construction industry.

Additional information
Please take note of the following details regarding your participation:

- This project has been approved by the University of South Australia's Human Research Committee Ethics Protocol 202659. If you have any ethical concerns about the project or questions about your rights as a participant, please contact the Executive Officer of this Committee, Tel: +618 8302 6330; email: humanethics@unisa.edu.au
- Please be aware you are required to complete the enclosed consent form before participating in this research.
- It is not anticipated that there are any risks to participation in this study beyond those encountered during everyday life.
- While we would be pleased to have you participate, we respect your right to decline. Participation in this study is voluntary, and participants are free to withdraw from the research project without affecting their current or future position. However, after data has been re-identified, it will not be possible to withdraw your individual data from the research as all identifying details will be removed.
- The certified transcript of the tape is raw data and will be securely retained for five years. During the research, the soft copies will be stored in a password-protected computer, and no one else can access the research data and results except the researcher.
- All records containing personal information will remain confidential, and no information which could lead to the identification of any individual will be released unless required by law.
- Participants also can choose to omit or not respond to questions and choose to omit or ask to delete any data supplied

Research feedback
A summary of the research findings will be available by 2022 and can be arranged to send to you at your request.

I strongly believe that your support is vital for the completion of my research, and I greatly appreciate your valued time and cooperation.

Yours Sincerely,

Chamitha Wijewickrama,
PhD Candidate [redacted]
Email: madduma_kaluge.wijewickrama@mymail.unisa.edu.au

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Appendix 1(C): Semi-structured Interview Guideline

Project title: Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

The researcher's use only

Code:	Date:
Duration:	Venue:

1. Can you describe your **current role** in this organization?
2. How many **years of experience** do you have in the **waste management sector**?

Process for Quality Assurance

3. What **process** needs to be followed to ensure the quality of reprocessed products during the following operational phases in the reverse logistics supply chains of demolition waste?
    - ✓ Building dismantling and on-site processing phase
    - ✓ Off-site waste processing phase

People for Quality Assurance

4. Who are the main **internal stakeholders** engaged in ensuring the quality of reprocessed products during the following operational phases in the reverse logistics supply chains of demolition waste?
    - ✓ Building dismantling and on-site processing phase
    - ✓ Off-site waste processing phase
5. Explain how the above internal stakeholders in the reverse logistics supply chains are important for quality assurance in the supply chain?

Policy for Quality Assurance

6. What are the **policies** [regulations, standards, guidelines] and other quality-related documents [work instructions, company policies, quality management plans etc.] that need to ensure the quality of reprocessed products during these operational phases in the reverse logistics supply chains of demolition waste?
    - ✓ Building dismantling and on-site processing phase
    - ✓ Off-site waste processing phase
7. Explain how these policies are important for quality assurance in the supply chain?

Technology for Quality Assurance

8. What **technologies** [plant, equipment, machinery, techniques, approaches, etc.] need to ensure the quality of reprocessed products during these operational phases in the reverse logistics supply chains of demolition waste?
    - ✓ Building dismantling and on-site processing phase
    - ✓ Off-site waste processing phase
9. Explain how these technologies are important for quality assurance in the supply chain?

Information for Quality Assurance

10. What **information** is available for quality assurance during these operational phases in the reverse logistics supply chains of demolition waste?
    - ✓ Building dismantling and on-site processing phase
    - ✓ Off-site waste processing phase
11. What information is not available for quality assurance?
12. Why is some information not available?
13. What are the mechanisms that could undertake to overcome these information deficiencies?
14. What are the existing barriers to quality assurance in reverse logistics supply chains of demolition waste?
15. What are the measures that could undertake to overcome those barriers?

THANK YOU!

Appendix 2(A): Consent Form: Structured Interviews

University of South Australia

Human Research Ethics Committee
Consent Form

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Contact Details	[redacted]
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Contact Details	Associate Professor Nicholas Chileshe [redacted] Associate Professor Rameez Ramezdeen [redacted] Dr Jorge Ochoa Paniagua [redacted] Mr Jim Fairweather [redacted]
Project Number	202659
Project Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

SECTION 2: PARTICIPANT CERTIFICATION

In signing this form, I confirm that:

- I have read the Participant Information Sheet, and the nature and the purpose of the research project have been explained to me. I understand and agree to take part.
- I understand the nature of my involvement in the project.
- I understand that I may not directly benefit from taking part in the project.
- I understand that I can withdraw from the project at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that I will be audiotaped during the study.
- I understand that while information gained during the project may be published, I will not be identified, and my personal results will remain confidential unless required by law.
- I understand that all data collected during the project (including a copy of the audio recordings) will be securely stored in a password-protected computer file for a period of five years only under the accessibility of the researcher and supervisors.

Participant's Signature	*Printed Name*	*Date*

SECTION 3: RESEARCHER CERTIFICATION

I have explained the study to the participant and consider that he/she understand what is involved.

Researcher Signature	*Printed Name*	*Date*

Appendix 2(B): Information Sheet: Structured Interviews

University of South Australia

UniSA STEM

PARTICIPANT INFORMATION SHEET – STRUCTURED INTERVIEWS

Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste
Project Number	202659
Chief Investigator	Madduma Kaluge Chamitha Sanjani Wijewickrama
Supervisor	Associate Professor Nicholas Chileshe Associate Professor Rameez Rameezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather

Dear Sir/Madam,

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Purpose of the research

Issues related to the quality of reprocessed products and information deficiency have been found as major hurdles affecting the Reverse Logistics Supply Chains (RLSCs) of demolition waste (DW). Quality assurance (QA) plays a significant role in ensuring the final product's quality. However, the lack of information (epistemic uncertainties) challenges the QA of the RLSCs. Consequently, this research aims to identify and evaluate the epistemic uncertainties involved in RLSCs and the mechanisms that could respond to those. The research intends to develop an information processing model for QA in RLSCs of DW.

The objectives of doing the research

The expectations of this research are summarized in the following objectives.

- To establish how the process, people, policy and technology contribute to the quality assurance in reverse logistics supply chains of demolition waste
- To identify epistemic uncertainties that lead to information processing needs and corresponding information-processing mechanisms for quality assurance in reverse logistics supply chains
- To develop an information processing model for quality assurance in reverse logistics supply chains and empirically validate the model
- To assess the applicability of the information processing model for quality assurance within real reverse supply chain contexts

What you expect to do in the research

The purpose of doing the structured interviews is to determine the cause-and-effect relationships between identified: (i) epistemic uncertainties and (ii) epistemic uncertainties and information processing mechanisms (IPMs). If you are willing to participate in this research project, you are kindly requested to express your perceptions and observations regarding the cause-and-effect relationships between the above variables that are foundational in developing the information-centric QA model for RLSC of DW. The interview will last for nearly 60-90 minutes.

Benefits to the participant
This research will ultimately improve the QA of RLSCs in construction by making the information as the supporting tool. In the end, the participant will also be given the opportunity to receive a summary of the collated results upon request, which may indirectly support advancing reprocessed products' popularity in the construction industry.

Additional information
Please take note of the following details regarding your participation:

- This project has been approved by the University of South Australia's Human Research Committee Ethics Protocol 202659. If you have any ethical concerns about the project or questions about your rights as a participant, please contact the Executive Officer of this Committee, Tel: +618 8302 6330; email: humanethics@unisa.edu.au
- Please be aware you are required to complete the enclosed consent form before participating in this research.
- It is not anticipated that there are any risks to participation in this study beyond those encountered during everyday life.
- While we would be pleased to have you participate, we respect your right to decline. Participation in this study is voluntary, and participants are free to withdraw from the research project without affecting their current or future position. However, after data has been re-identified it will not be possible to withdraw your individual data from the research as all identifying details will be removed.
- The certified transcript of the tape is raw data and will be securely retained for five years. During the research, the soft copies will be stored in a password-protected computer, and no one else can access the research data and results except the researcher.
- All records containing personal information will remain confidential, and no information which could lead to the identification of any individual will be released unless required by law.
- Participants also can choose to omit or not respond to questions and choose to omit or ask to delete any data supplied

Research feedback
A summary of the research findings will be available by 2022 and can be arranged to send to you at your request.

I strongly believe that your support is vital for the completion of my research, and I greatly appreciate your valued time and cooperation.

Yours Sincerely,

Chamitha Wijewickrama,
PhD Candidate [redacted]
Email: madduma_kaluge.wijewickrama@mymail.unisa.edu.au

Supervisors' Names & Contact Details:

Assoc. Prof. Nicholas Chileshe (University of South Australia)
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Assoc. Prof. Rameez Rameezdeen (University of South Australia)
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Dr. Jorge Ochoa Paniagua (University of South Australia)
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Jim Fairweather (ResourceCo Pty Ltd)
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E-mail: jfairweather@resourceco.com.au

Appendix 2(C): Structured Interview Guideline

Project title: Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

The researcher's use only

Code:	Date:
Duration:	Venue:

1. Can you describe your **current role** in this organization?
2. How many **years of experience** do you have in the **waste management sector**?
3. In this interview guideline, you have provided two tables: **Table A** and **Table B**. Please follow the following instructions to complete the Tables.

Table A:

You are provided with a table that includes.

- ✓ List of epistemic uncertainties (i.e., information deficiencies) you encountered for quality assurance during the operational phases of building dismantling and on-site and off-site waste processing.
- ✓ The same list of epistemic uncertainties was repeated in the table, in the third column as causes and in the third row as effects.
- ✓ Please conduct a pairwise comparison between each two epistemic uncertainties and rate the relationships as per the scale

  0 = No Relationship 1 = Weak Relationship 2 = Strong Relationship
  3 = Very Strong Relationship

e.g.

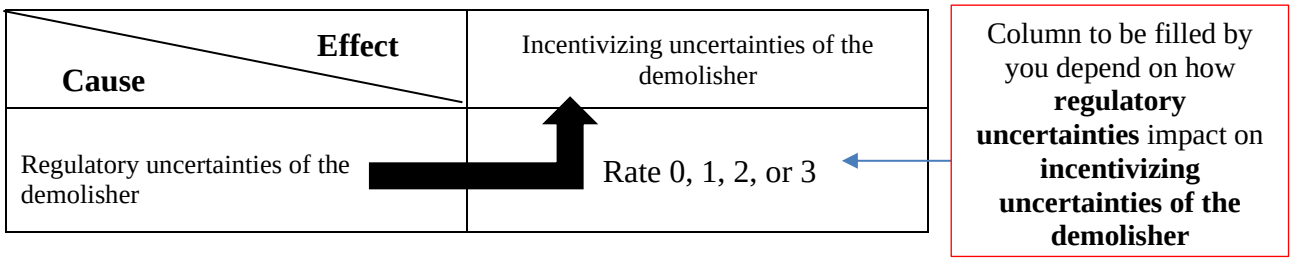

Table A: Rate the relationships between each two epistemic uncertainties using the following criteria.

0 = No Relationship 1 = Weak Relationship 2 – Strong Relationship 3 – Very Strong Relationship

			Effects																	
	Operational phases in reverse logistics supply chains of demolition waste		**Building dismantling and on-site waste processing**								**Off-site waste processing**								**Quality assurance of the supply chain**
	Operational phases in reverse logistics supply chains of demolition waste	**Epistemic uncertainties that lead to information processing needs (IPNs)**	Regulatory uncertainties of the demolisher	Incentivizing uncertainties of the demolisher	Contractual uncertainties from forward supply chain-upstream actors	Management of demolisher's sub-contractors	As-is condition of the building	Management of contaminated/ hazardous substances	Health and safety concerns of the demolisher	Workflow uncertainties of the demolisher	Regulatory uncertainties of the waste processor	Incentivizing uncertainties of the waste processor	Contractual uncertainties from forward supply chain-downstream actors	Mixed waste received from the demolishers	Product description complexities	Human errors	Health and safety concerns of the waste processor	Workflow uncertainties of the waste processor	
Causes	**Building dismantling and on-site waste processing**	Regulatory uncertainties of the demolisher																		
		Incentivizing uncertainties of the demolisher																		
		Contractual uncertainties from forward supply chain-upstream actors																		
		Management of demolisher's sub-contractors																		
		As-is condition of the building																		
		Management of contaminated/ hazardous substances																		
		Health and safety concerns of the demolisher																		
		Workflow uncertainties of the demolisher																		
	Off-site waste processing	Regulatory uncertainties of the waste processor																		
		Incentivizing uncertainties of the waste processor																		
		Contractual uncertainties from forward supply chain-downstream actors																		
		Mixed waste received from the demolishers																		
		Product description complexities																		
		Human errors																		
		Health and safety concerns of the waste processor																		
		Workflow uncertainties of the waste processor																		

Table B:

You are provided with a table that includes;

- ✓ The information processing mechanisms (IPMs) in the second column as causes, and epistemic uncertainties in the third row as effects
- ✓ Please conduct a pairwise comparison between IPMs and epistemic uncertainties and rate the relationship as per the given scale, considering how effectively each IPM responds to epistemic uncertainties.

  0 = No Relationship 1 = Weak Relationship 2 = Strong Relationship

  3 = Very Strong Relationship

e.g.

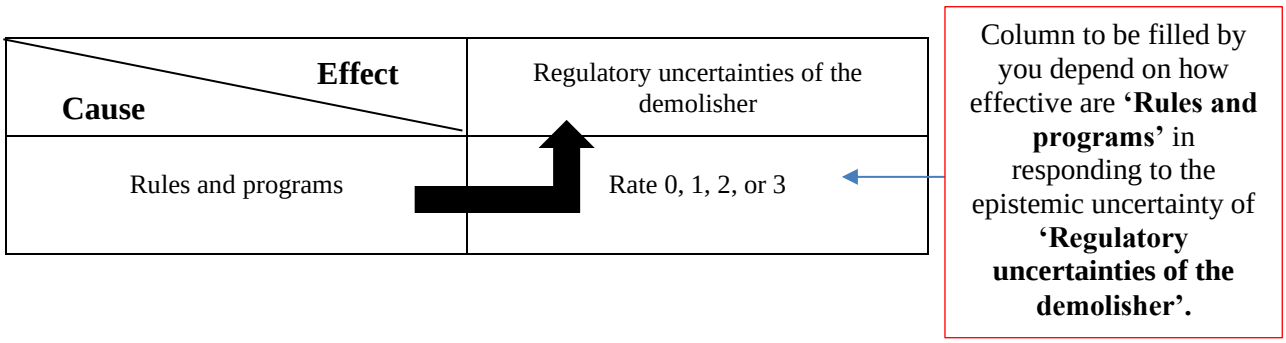

Table B: Rate how the following IPMs could respond to each epistemic uncertainty using the following criteria.

0 = No Relationship **1 = Weak Relationship** **2 – Strong Relationship** **3 – Very Strong Relationship**

Causes	Effects																
	Operational phases in reverse logistics supply chains of demolition waste	**Building dismantling and on-site waste processing**								**Off-site waste processing**							
	Epistemic uncertainties that lead to IPNs / IPMs	Regulatory uncertainties of the demolisher	Incentivizing uncertainties of the demolisher	Contractual uncertainties from forward supply chain-upstream actors	Management of demolisher's sub-contractors	As-is condition of the building	Management of contaminated/ hazardous substances	Health and safety concerns of the demolisher	Workflow uncertainties of the demolisher	Regulatory uncertainties of the waste processor	Incentivizing uncertainties of the waste processor	Contractual uncertainties from forward supply chain-downstream actors	Mixed waste received from the demolishers	Product description complexities	Human errors	Health and safety concerns of the waste processor	Workflow uncertainties of the waste processor
	Rules and programs																
	Planning and goal setting																
	Business partnering																
	Collection of building documents and asbestos registers																
	Site visits/ pre-demolition audits																
	Creation of integrator roles																
	Performance evaluation of sub-contractors																
	Waste acceptance criteria/ gate fees																
	Forming contracts																
	Creation of special reports																
	Investment in technologies																
	Group meetings																
	Hierarchical referral																
	Incorporation of self-contained groups																
	Creation of slack resources																

Appendix 3(A): Consent Form: Focus Group Discussion

University of South Australia

Human Research Ethics Committee
Consent Form

This project has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant please contact the Executive Officer of this Committee, Tel: [redacted]; Email: humanethics@unisa.edu.au.

SECTION 1: CONTACT AND PROJECT DETAILS	
Researcher's Full Name	Madduma Kaluge Chamitha Sanjani Wijewickrama
Contact Details	[redacted]
Supervisor's Name *(students only)*	Associate Professor Nicholas Chileshe Associate Professor Rameez Ramezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather
Contact Details	Associate Professor Nicholas Chileshe [redacted] Associate Professor Rameez Ramezdeen [redacted] Dr Jorge Ochoa Paniagua [redacted] Mr Jim Fairweather [redacted]
Project Number	202659
Project Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

SECTION 2: PARTICIPANT CERTIFICATION

In signing this form, I confirm that:

- I have read the Participant Information Sheet, and the nature and the purpose of the research project have been explained to me. I understand and agree to take part.
- I understand the nature of my involvement in the project.
- I understand that I may not directly benefit from taking part in the project.
- I understand that I can withdraw from the project at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that I will be audiotaped during the study.
- I understand that while information gained during the project may be published, I will not be identified, and my personal results will remain confidential unless required by law.
- I understand that all data collected during the project (including a copy of the audio recordings) will be securely stored in a password-protected computer file for a period of five years only under the accessibility of the researcher and supervisors.

Participant's Signature	*Printed Name*	*Date*

SECTION 3: RESEARCHER CERTIFICATION

I have explained the study to the participant and consider that he/she understand what is involved.

Researcher Signature	*Printed Name*	*Date*

Appendix 3(B): Information Sheet: Focus Group Discussion



UniSA STEM

PARTICIPANT INFORMATION SHEET – FOCUS GROUP DISCUSSION

Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste
Project Number	202659
Chief Investigator	Madduma Kaluge Chamitha Sanjani Wijewickrama
Supervisor	Associate Professor Nicholas Chileshe Associate Professor Rameez Rameezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather

Dear Sir/Madam,

I am a HDR student attached to UniSA STEM. You are kindly invited to take part in my PhD research project titled, **"Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste".**

Purpose of the research

Issues related to the quality of reprocessed products and information deficiency have been found as major hurdles affecting the Reverse Logistics Supply Chains (RLSCs) of demolition waste (DW). Quality assurance (QA) plays a significant role in ensuring the final product's quality. However, the lack of information (epistemic uncertainties) challenges the QA of the RLSCs. Consequently, this research aims to identify and evaluate the epistemic uncertainties involved in RLSCs and the mechanisms that could respond to those. The research intends to develop an information processing model for QA in RLSCs of DW.

The objectives of doing the research

The expectations of this research are summarized in the following objectives.

- To establish how the process, people, policy and technology contribute to the quality assurance in reverse logistics supply chains of demolition waste
- To identify epistemic uncertainties that lead to information processing needs and corresponding information-processing mechanisms for quality assurance in reverse logistics supply chains
- To develop an information processing model for quality assurance in reverse logistics supply chains and empirically validate the model
- To assess the applicability of the information processing model for quality assurance within real reverse supply chain contexts

What you expect to do in the research

The purpose of doing the focus group discussion is to empirically validate the information processing model for QA in RLSCs of DW. This model consists of cause-and-effect relationships between (i) epistemic uncertainties and (ii) epistemic uncertainties and information processing mechanisms (IPMs) for QA in RLSC of DW. If you are willing to participate in this research project, you are requested to express your views, opinions, and suggestions to improve the status-quo representation of the information processing model for QA in RLSCs of DW. The focus group discussion will last for nearly 90-120 minutes.

Benefits to the participant
This research will ultimately improve the QA of RLSCs in construction by making the information the supporting tool. In the end, the participant will also be given the opportunity to receive a summary of the collated results upon request, which may indirectly support advancing reprocessed products' popularity in the construction industry.

Additional information
Please take note of the following details regarding your participation:

- This project has been approved by the University of South Australia's Human Research Committee Ethics Protocol 202659. If you have any ethical concerns about the project or questions about your rights as a participant, please contact the Executive Officer of this Committee, Tel: +618 8302 6330; email: humanethics@unisa.edu.au
- Please be aware you are required to complete the enclosed consent form before participating in this research.
- It is not anticipated that there are any risks to participation in this study beyond those encountered during everyday life.
- While we would be pleased to have you participate, we respect your right to decline. Participation in this study is voluntary, and participants are free to withdraw from the research project without affecting their current or future position. However, after data has been re-identified it will not be possible to withdraw your individual data from the research as all identifying details will be removed.
- The certified transcript of the tape is raw data and will be securely retained for five years. During the research, the soft copies will be stored in a password-protected computer, and no one else can access the research data and results except the researcher.
- All records containing personal information will remain confidential, and no information which could lead to the identification of any individual will be released unless required by law.
- Participants also can choose to omit or not respond to questions and choose to omit or ask to delete any data supplied

Research feedback
A summary of the research findings will be available by 2022 and can be arranged to send to you at your request.

I strongly believe that your support is vital for the completion of my research, and I greatly appreciate your valued time and cooperation.

Yours Sincerely,

Chamitha Wijewickrama,
PhD Candidate [redacted]
Email: madduma_kaluge.wijewickrama@mymail.unisa.edu.au

Supervisors' Names & Contact Details:

Assoc. Prof. Nicholas Chileshe (University of South Australia)
Tel: [redacted]
E-mail: nicholas.chileshe@unisa.edu.au

Assoc. Prof. Rameez Rameezdeen (University of South Australia)
Tel: [redacted]
E-mail: rameez.rameezdeen@unisa.edu.au

Dr. Jorge Ochoa Paniagua (University of South Australia)
Tel[redacted]
E-mail: Jorge.OchoaPaniagua@unisa.edu.au

Jim Fairweather (ResourceCo Pty Ltd)
Tel: [redacted]
E-mail: jfairweather@resourceco.com.au

Appendix 3(C): Focus Group Guide

Project title: Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

The researcher's use only

No. of participants:	Date:
Duration:	Venue:

1. Can each of you describe your **current role** in your organization?
2. How many **years of experience** do you have in the **waste management sector**?

(Each participant in the focus group discussion was provided with the status-quo representation of the information processing model developed after the structured interviews. The moderator explained the process followed in developing the model and guided the discussion with the following instructions)

3. You have provided an information processing model for quality assurance in reverse logistics supply chains of demolition waste. Review the identified cause-and-effect relationships in the model. Suggest any alterations that could be made to the status-quo representation of the model (if necessary) as it is feasible to apply in the real context of reverse logistics supply chains of demolition waste.
    a. Suggestions to add/remove nodes to/from the model
    b. Suggestions to add/remove the cause-and-effect relationships between;
        i. Epistemic uncertainties
        ii. Epistemic uncertainties and the QA in RLSC of DW
        iii. Information processing mechanisms and epistemic uncertainties
    c. Overall comment on the feasibility of using the developed model in the real context.

Appendix 4(A): Consent Form: Case Study

University of South Australia

Human Research Ethics Committee
Consent Form

This project has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant please contact the Executive Officer of this Committee, Tel: [redacted]; Email: humanethics@unisa.edu.au.

SECTION 1: CONTACT AND PROJECT DETAILS	
Researcher's Full Name	Madduma Kaluge Chamitha Sanjani Wijewickrama
Contact Details	[redacted]
Supervisor's Name *(students only)*	Associate Professor Nicholas Chileshe Associate Professor Rameez Ramezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather
Contact Details	Associate Professor Nicholas Chileshe [redacted] Associate Professor Rameez Ramezdeen [redacted] Dr Jorge Ochoa Paniagua [redacted] Mr Jim Fairweather [redacted]
Project Number	202659
Project Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

SECTION 2: PARTICIPANT CERTIFICATION

In signing this form, I confirm that:

- I have read the Participant Information Sheet, and the nature and the purpose of the research project have been explained to me. I understand and agree to take part.
- I understand the nature of my involvement in the project.
- I understand that I may not directly benefit from taking part in the project.
- I understand that I can withdraw from the project at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that I will be audiotaped during the study.
- I understand that while information gained during the project may be published, I will not be identified, and my personal results will remain confidential unless required by law.
- I understand that all data collected during the project (including a copy of the audio recordings) will be securely stored in a password-protected computer file for a period of five years only under the accessibility of the researcher and supervisors.

Participant's Signature	*Printed Name*	*Date*

SECTION 3: RESEARCHER CERTIFICATION

I have explained the study to the participant and consider that he/she understand what is involved.

Researcher Signature	*Printed Name*	*Date*

Appendix 4(B): Information Sheet: Case Study



UniSA STEM

PARTICIPANT INFORMATION SHEET – Focus Group Discussion

Title	Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste
Project Number	202659
Chief Investigator	Madduma Kaluge Chamitha Sanjani Wijewickrama
Supervisor	Associate Professor Nicholas Chileshe Associate Professor Rameez Rameezdeen Dr Jorge Ochoa Paniagua Mr Jim Fairweather

Dear Sir/Madam,

I am a HDR student attached to UniSA STEM. You are kindly invited to take part in my PhD research project titled, **"Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste".**

Purpose of the research

Issues related to the quality of reprocessed products and information deficiency have been found as major hurdles affecting the Reverse Logistics Supply Chains (RLSCs) of demolition waste (DW). Quality assurance (QA) plays a significant role in ensuring the final product's quality. However, the lack of information (epistemic uncertainties) challenges the QA of the RLSCs. Consequently, this research aims to identify and evaluate the epistemic uncertainties involved in RLSCs and the mechanisms that could respond to those. The research intends to develop an information processing model for QA in RLSCs of DW.

The objectives of doing the research

The expectations of this research are summarized in the following objectives.

- To establish how the process, people, policy and technology contribute to the quality assurance in reverse logistics supply chains of demolition waste
- To identify epistemic uncertainties that lead to information processing needs and corresponding information-processing mechanisms for quality assurance in reverse logistics supply chains
- To develop an information processing model for quality assurance in reverse logistics supply chains and empirically validate the model
- To assess the applicability of the information processing model for quality assurance within real reverse supply chain contexts

What you expect to do in the research

The purpose of doing case studies is to assess the applicability of the information processing QA model in the real context of RLSCs of DW. If you are willing to participate in this research project, you are requested to populate the probabilities in the conditional probability tables (the researcher will explain this more during the exercise). Based on the assigned probabilities, the epistemic uncertainty propagation of the model could be computed, making myriads of conclusions over the quality performance of the selected RLSC of DW. The estimated time for the exercise will be approximately 90-120 minutes.

Benefits to the participant
This research will ultimately improve the QA of RLSCs in construction by making the information as the supporting tool. In the end, the participant will also be given the opportunity to receive a summary of the collated results upon request, which may indirectly support advancing reprocessed products' popularity in the construction industry.

Additional information
Please take note of the following details regarding your participation:

- This project has been approved by the University of South Australia's Human Research Committee Ethics Protocol 202659. If you have any ethical concerns about the project or questions about your rights as a participant, please contact the Executive Officer of this Committee, Tel: +618 8302 6330; email: humanethics@unisa.edu.au
- Please be aware you are required to complete the enclosed consent form before participating in this research.
- It is not anticipated that there are any risks to participation in this study beyond those encountered during everyday life.
- While we would be pleased to have you participate, we respect your right to decline. Participation in this study is voluntary, and participants are free to withdraw from the research project without affecting their current or future position. However, after data has been re-identified it will not be possible to withdraw your individual data from the research as all identifying details will be removed.
- The certified transcript of the tape is raw data and will be securely retained for five years. During the research, the soft copies will be stored in a password-protected computer, and no one else can access the research data and results except the researcher.
- All records containing personal information will remain confidential, and no information which could lead to the identification of any individual will be released, unless required by law.
- Participants also can choose to omit or not respond to questions and choose to omit or ask to delete any data supplied

Research feedback
A summary of the research findings will be available by 2022 and can be arranged to send to you at your request.

I strongly believe that your support is vital for the completion of my research, and I greatly appreciate your valued time and cooperation.

Yours Sincerely,

Chamitha Wijewickrama,
PhD Candidate [redacted]
Email: madduma_kaluge.wijewickrama@mymail.unisa.edu.au

Supervisors' Names & Contact Details:

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Assoc. Prof. Rameez Rameezdeen (University of South Australia)
Tel[redacted]
E-mail: rameez.rameezdeen@unisa.edu.au

Dr. Jorge Ochoa Paniagua (University of South Australia)
Tel: [redacted]
E-mail: Jorge.OchoaPaniagua@unisa.edu.au

Jim Fairweather (ResourceCo Pty Ltd)
Tel: [redacted]
E-mail: jfairweather@resourceco.com.au

Appendix 4(C): Case Study Guideline

Project title: Development of an Information Processing Model for Quality Assurance in Reverse Logistics Supply Chains of Demolition Waste

The researcher's use only

No. of participants:	Date:
Duration:	Venue:

1. Can each of you describe your **current role** in your organization?
2. How many **years of experience** do you have in the waste management sector?
3. Could you please give a brief **introduction to your organization**?
   - ✓ When was it established
   - ✓ Approximate annual turnover (more/ less than $250 million)
   - ✓ Number of current employees in the organization
   - ✓ Accreditations and licenses of the organization
   - ✓ Products and services produced by the organization
   - ✓ The relationship between both organizations (demolisher and waste processor)

Information processing mechanisms of the organizations

4. Please indicate in the following table the information processing mechanisms you are currently undertaking in your organizations.

The demolition organization		**The waste processing organization**	
Information processing mechanisms	**Whether undertaking (√) or not (X)**	**Information processing mechanisms**	**Whether undertaking (√) or not (X)**
Rules and programs		Rules and programs	
Planning and goal setting		Planning and goal setting	
Business partnering		Business partnering	
Collection of building documents and asbestos registers		Creation of integrator roles	
Site visits/ pre-demolition audits		Waste acceptance criteria/ gate fees	
Performance evaluation of sub-contractors		Forming contracts	
Forming contracts		Creation slack resources	
Investment in technologies		Investment in technologies	
Group meetings		Group meetings	
Hierarchical referral		Hierarchical referral	
Incorporation of self-contained groups		Incorporation of self-contained groups	
Creation slack resources		Creation of special reports	

Development of conditional probability tables

The focus group participants have provided the conditional probability tables of each node in the developed information processing quality assurance model.

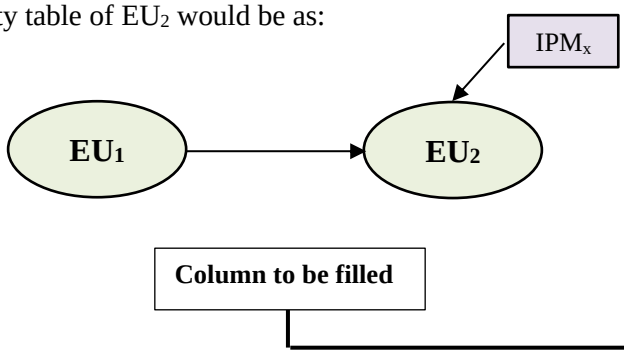
5. Fill up the following **conditional probability tables** of each node by considering the conditional probabilities using the given scale. An example has been done for your understanding. (Note: if your organizations are not currently undertaking any of the information processing mechanisms, fill the tables assuming what would be the effect of such mechanisms if those are undertaken in the organization)

Classification	Range
Almost certain	0.99-1
Highly likely	0.8-0.99
Likely	0.6-0.8
Fifty-fifty	0.4-0.6
Unlikely	0.2-0.4
Highly unlikely	0-0.2

Table A1: The scale used for eliciting probability values

State conditional probabilities of the following nodes based on the given scale

Example: Suppose there are two epistemic uncertainties, such as EU_1 and EU_2. As shown in the following figure, IPM_x could be undertaken in response to the EU_2. If so, the conditional probability table of EU_2 would be as:



EU1	IPMx	EU2	
		Yes	No
Yes	Yes	0.7500	0.2500
	No	0.4500	0.5500
No	Yes	0.8800	0.1200
	No	0.6600	0.3500

Figure A1: Example of probability eliciting of chance nodes

X_1. Regulatory uncertainties of the demolisher

IPM1. Rules and programs	X1. Regulatory uncertainties of the demolisher	
	Yes	No
Yes		
No		

X_2. Incentivizing uncertainties of the demolisher

X_1. Regulatory uncertainties of the demolisher	IPM_3. Business partnering	X_2. Incentivizing uncertainties of the demolisher	
		Yes	No
Yes	Yes		
	No		
No	Yes		
	No		

X_3. Contractual uncertainties from forward supply chain-upstream actors

X_1. Regulatory uncertainties of the demolisher	X_2. Incentivizing uncertainties of the demolisher	IPM_2. Planning and goal setting	X_3. Contractual uncertainties from forward supply chain-upstream actors	
			Yes	No
Yes	Yes	Yes		
		No		
	No	Yes		
		No		
No	Yes	Yes		
		No		
	No	Yes		
		No		

X_4. Management of demolisher's sub-contractors

X_3. Contractual uncertainties from forward supply chain-upstream actors	IPM_{12}. Group meetings	IPM_7. Performance evaluation of sub-contractors	IPM_9. Forming contracts	X_4. Management of demolisher's sub-contractors	
				Yes	No
Yes	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		
No	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		

X_5. As-is condition of the building

X_3. Contractual uncertainties from forward supply chain-upstream actors	IPM_{13}. Hierarchical referral	IPM_5. Site visits/ pre-demolition audits	IPM_4. Collection of building documents and asbestos registers	X_5. As-is condition of the building	
				Yes	No
Yes	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		
No	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		

X_6. Management of contaminated/ hazardous substances

X_1. Regulatory uncertainties of the demolisher	X_5. As-is condition of the building	IPM_{11}. Investment in technologies	IPM_{14}. Incorporation of self-contained groups	X_6. Management of contaminated/ hazardous substances	
				Yes	No
Yes	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		
No	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		

X_7. Health and safety concerns of the demolisher

X_6. Management of contaminated/ hazardous substances	X_5. As-is condition of the building	X_4. Management of demolisher's sub-contractors	IPM_{15}. Creation of slack resources	X_7. Health and safety concerns of the demolisher	
				Yes	No
Yes	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		
No	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		

X_8. Workflow uncertainties of the demolisher

X_1. Regulatory uncertainties of the demolisher	X_3. Contractual uncertainties from forward supply chain-upstream actors	X7. Health and safety concerns of the demolisher	X_6. Management of contaminated/ hazardous substances	X_4. Management of demolisher's sub-contractors	X_8. Workflow uncertainties of the demolisher	
					Yes	No
Yes	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
No	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		

X_9. Regulatory uncertainties of the waste processor

IPM_1. Rules and programs	X_9. Regulatory uncertainties of the waste processor	
	Yes	No
Yes		
No		

X_{10}. Incentivizing uncertainties of the waste processor

X_9. Regulatory uncertainties of the demolisher	IPM_3. Business partnering	X_{10}. Incentivizing uncertainties of the waste processor	
		Yes	No
Yes	Yes		
	No		
No	Yes		
	No		

X_{11}. Contractual uncertainties from forward supply chain-downstream actors

X_9. Regulatory uncertainties of the waste processor	X_{10}. Incentivizing uncertainties of the waste processor	IPM_2. Planning and goal setting	X_{11}. Contractual uncertainties from forward supply chain-downstream actors	
			Yes	No
Yes	Yes	Yes		
		No		
	No	Yes		
		No		
No	Yes	Yes		
		No		
	No	Yes		
		No		

X_{15}. Health and safety concerns of the waste processor

X_9. Regulatory uncertainties of the waste processor	X_{12}. Mixed waste received from the demolishers	X_{14}. Human errors	IPM_{15}. Creation of slack resources	X_{15}. Health and safety concerns of the demolisher	
				Yes	No
Yes	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		
No	Yes	Yes	Yes		
			No		
		No	Yes		
			No		
	No	Yes	Yes		
			No		
		No	Yes		
			No		

X_{12}. Mixed waste received from the demolishers

X_8. Workflow uncertainties of the demolisher	X_{14}. Human errors	IPM_9. Forming contracts	IPM_8. Waste acceptance criteria/ gate fees	IPM_6. Creation of integrator roles	X_{12}. Mixed waste received from the demolishers	
					Yes	No
Yes	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
No	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		

X_{13}. Product description complexities

X_{11}. Contractual uncertainties from forward supply chain-downstream actors	IPM_{12}. Group meetings	IPM_{10}. Creation of special reports	X_{13}. Product description complexities	
			Yes	No
Yes	Yes	Yes		
		No		
	No	Yes		
		No		
No	Yes	Yes		
		No		
	No	Yes		
		No		

X_{14}. Human errors

X_{10}. Incentivizing uncertainties of the waste	X_{13}. Product description complexities	IPM_{14}. Incorporation of self-contained	IPM_{13}. Hierarchical referral	IPM_{11}. Investment of technologies	X_{14}. Human errors	
					Yes	No
Yes	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
No	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		

X_{16}. Workflow uncertainties of the waste processor

X_9. Regulatory uncertainties of the waste processor	X_{13}. Product description complexities	X_{12}. Mixed waste received from the demolishers	X_{14}. Human errors	X_{15}. Health and safety concerns of the demolisher	X_8. Workflow uncertainties of the demolisher	
					Yes	No
Yes	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
No	Yes	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		
	No	Yes	Yes	Yes		
				No		
			No	Yes		
				No		
		No	Yes	Yes		
				No		
			No	Yes		
				No		

Y. Quality assurance (QA) of the reverse logistics supply chains (RLSCs) of demolition waste (DW) - utility value

Classification	Range
Maximum	1
Very high	0.8-1
High	0.6-0.8
Medium	0.4-0.6
Low	0.2-0.4
Very low	0-0.2
Minimum	0

Table A2: The scale used for eliciting utility values

X_8. Workflow uncertainties of the demolisher	X_{16}. Workflow uncertainties of the waste processor	Y. QA in RLSC of DW (utility value)
Yes	**Yes**	
	No	
No	**Yes**	
	No	

Appendix 5(A): Case I - Summary of Conditional Probability Tables

X_1. Regulatory uncertainties of the demolisher

IPM_1. Rules and programs	Yes	No
Yes	0.11	0.74
No	0.89	0.26

X_2. Incentivizing uncertainties of the demolisher

X_1. Regulatory uncertainties of the demolisher	Yes		No	
IPM_3. Business partnering	Yes	No	Yes	No
Yes	0.65	0.72	0.06	0.1
No	0.35	0.28	0.94	0.9

X_3. Contractual uncertainties from forward supply chain-upstream actors

X_1. Regulatory uncertainties of the demolisher	Yes				No			
X2. Incentivizing uncertainties of the demolisher	Yes		No		Yes		No	
IPM_2. Planning and goal setting	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.55	0.91	0.5	0.82	0.1	0.45	0.08	0.32
No	0.45	0.09	0.5	0.18	0.9	0.55	0.92	0.68

X_4. Management of demolisher's sub-contractors

X_3. Contractual uncertainties from forward supply chain - upstream actors	Yes								No							
IPM_{12}. Group meetings	Yes				No				Yes				No			
IPM_7. Performance evaluation of sub-contractors	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_9. Forming contracts	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.20	0.56	0.30	0.64	0.25	0.58	0.52	0.72	0.13	0.51	0.28	0.61	0.22	0.52	0.42	0.65
No	0.80	0.44	0.70	0.36	0.75	0.42	0.48	0.28	0.87	0.49	0.72	0.39	0.78	0.48	0.58	0.35

X_5. As-is condition of the building

X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
IPM_{13}. Hierarchical referral	Yes				No				Yes				No			
IPM_5. Site visits/ pre-demolition audits	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_4. Collection of building documents and asbestos registers	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.20	0.61	0.58	0.75	0.29	0.56	0.53	0.78	0.08	0.57	0.53	0.68	0.18	0.50	0.50	0.72
No	0.80	0.39	0.42	0.25	0.71	0.44	0.47	0.22	0.92	0.43	0.47	0.32	0.82	0.50	0.50	0.28

X_6. Management of contaminated/ hazardous substances

X_1. Regulatory uncertainties of the demolisher	Yes								No							
X_5. As-is condition of the building	Yes				No				Yes				No			
IPM_{11}. Investment in technologies	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{14}. Incorporation of self-contained groups	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.62	0.40	0.42	0.12	0.82	0.81	0.78	0.26	0.70	0.65	0.60	0.21	0.87	0.68	0.65	0.60
No	0.38	0.60	0.58	0.88	0.18	0.19	0.22	0.74	0.30	0.35	0.40	0.79	0.13	0.32	0.35	0.40

X_7. Health and safety concerns of the demolisher

X_6. Management of contaminated/ hazardous substances	Yes								No							
X_5. As-is condition of the building	Yes				No				Yes				No			
X_4. Management of demolisher's sub-contractors	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{15}. Creation of slack resources	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.62	0.85	0.60	0.83	0.52	0.79	0.50	0.78	0.55	0.78	0.52	0.75	0.47	0.64	0.32	0.42
No	0.38	0.15	0.40	0.17	0.48	0.21	0.50	0.22	0.45	0.22	0.48	0.25	0.53	0.36	0.68	0.58

X_8. Workflow uncertainties of the demolisher

X_1. Regulatory uncertainties of the demolisher	Yes															
X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
X_7. Health and safety concerns of the demolisher	Yes				No				Yes				No			
X_6. Management of contaminated/ hazardous substances	Yes		No		Yes		No		Yes		No		Yes		No	
X_4. Management of demolisher's sub-contractors	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.99	0.95	0.70	0.68	0.93	0.86	0.65	0.62	0.75	0.72	0.65	0.62	0.70	0.68	0.60	0.57
No	0.01	0.05	0.30	0.32	0.07	0.14	0.35	0.38	0.25	0.28	0.35	0.38	0.30	0.32	0.40	0.43

X_1. Regulatory uncertainties of the demolisher	No															
X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
X_7. Health and safety concerns of the demolisher	Yes				No				Yes				No			
X_6. Management of contaminated/ hazardous substances	Yes		No		Yes		No		Yes		No		Yes		No	
X_4. Management of demolisher's sub-contractors	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.69	0.67	0.60	0.58	0.65	0.62	0.54	0.51	0.58	0.55	0.50	0.47	0.48	0.44	0.42	0.20
No	0.31	0.33	0.40	0.42	0.35	0.38	0.46	0.49	0.42	0.45	0.50	0.53	0.52	0.56	0.58	0.80

X_9. Regulatory uncertainties of the waste processor

IPM_1. Rules and programs	Yes	No
Yes	0.1	0.66
No	0.9	0.34

X_{10}. Incentivizing uncertainties of the waste processor

X_9. Regulatory uncertainties of the waste processor	Yes		No	
IPM_3. Business partnering	Yes	No	Yes	No
Yes	0.6	0.65	0.06	0.05
No	0.4	0.35	0.94	0.95

X_{11}. Contractual uncertainties from forward supply chain-downstream actors

X_9. Regulatory uncertainties of the waste processor	Yes				No			
X_{10}. Incentivizing uncertainties of the waste processor	Yes		No		Yes		No	
IPM_2. Planning and goal setting	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.55	0.93	0.48	0.88	0.32	0.29	0.11	0.23
No	0.45	0.07	0.52	0.12	0.68	0.71	0.89	0.77

X_{12}. Mixed waste received from the demolishers

X_8. Workflow uncertainties of the demolisher	Yes								No							
X_{14}. Human errors	Yes								Yes							
IPM_9. Forming contracts	Yes				No				Yes				No			
IPM_8. Waste acceptance criteria/ gate fees	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_6. Creation of integrator roles	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.25	0.55	0.82	0.76	0.58	0.61	0.79	0.85	0.25	0.55	0.82	0.76	0.58	0.59	0.79	0.84
No	0.75	0.45	0.18	0.24	0.42	0.39	0.21	0.15	0.75	0.45	0.18	0.24	0.42	0.41	0.21	0.16

X_8. Workflow uncertainties of the demolisher	Yes								No							
X_{14}. Human errors	Yes								Yes							
IPM_9. Forming contracts	Yes				No				Yes				No			
IPM_8. Waste acceptance criteria/ gate fees	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_6. Creation of integrator roles	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.05	0.11	0.20	0.19	0.12	0.17	0.22	0.72	0.05	0.11	0.20	0.19	0.12	0.17	0.22	0.69
No	0.95	0.89	0.80	0.81	0.88	0.83	0.78	0.29	0.95	0.89	0.80	0.81	0.88	0.83	0.78	0.32

X_{13}. Product description complexities

X_{11}. Contractual uncertainties from forward supply chain-downstream actors	Yes				No			
IPM_{12}. Group meetings	Yes		No		Yes		No	
IPM_{10}. Creation of special reports	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.23	0.7	0.4	0.79	0.15	0.22	0.19	0.25
No	0.77	0.3	0.6	0.21	0.85	0.78	0.81	0.75

X_{15}. Health and safety concerns of the waste processor

X_9. Regulatory uncertainties of the waste processor	Yes								No							
X_{12}. Mixed waste received from the demolishers	Yes				No				Yes				No			
X_{14}. Human errors	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{15}. Creation of slack resources	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.78	0.80	0.64	0.74	0.78	0.81	0.65	0.74	0.62	0.77	0.19	0.72	0.62	0.77	0.18	0.72
No	0.22	0.20	0.36	0.26	0.22	0.19	0.35	0.26	0.38	0.23	0.82	0.28	0.38	0.23	0.82	0.28

X_{14}. Human errors

X_{10}. Incentivizing uncertainties of the waste	Yes															
X_{13}. Product description complexities	Yes								No							
IPM_{14}. Incorporation of self-contained	Yes				No				Yes				No			
IPM_{13}. Hierarchical referral	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{11}. Investment of technologies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.60	0.73	0.71	0.69	0.92	0.78	0.75	0.81	0.46	0.50	0.62	0.63	0.72	0.70	0.69	0.71
No	0.40	0.27	0.29	0.31	0.08	0.22	0.25	0.19	0.54	0.50	0.38	0.37	0.28	0.30	0.31	0.29

X_{10}. Incentivizing uncertainties of the waste	Yes															
X_{13}. Product description complexities	Yes								No							
IPM_{14}. Incorporation of self-contained	Yes				No				Yes				No			
IPM_{13}. Hierarchical referral	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{11}. Investment of technologies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.55	0.65	0.69	0.65	0.89	0.72	0.72	0.74	0.12	0.07	0.08	0.56	0.11	0.63	0.62	0.65
No	0.45	0.35	0.31	0.35	0.11	0.28	0.28	0.26	0.88	0.93	0.92	0.44	0.89	0.37	0.38	0.35

X_{16}. Workflow uncertainties of the waste processor

X_9. Regulatory uncertainties of the waste processor	Yes															
X_{13}. Product description complexities	Yes								No							
X_{12}. Mixed waste received from the demolishers	Yes				No				Yes				No			
X_{14}. Human errors	Yes		No		Yes		No		Yes		No		Yes		No	
X_{15}. Health and safety concerns of the demolisher	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.99	0.92	0.88	0.85	0.74	0.72	0.70	0.65	0.80	0.78	0.77	0.74	0.52	0.50	0.48	0.45
No	0.01	0.08	0.12	0.15	0.26	0.28	0.30	0.35	0.20	0.22	0.23	0.26	0.48	0.50	0.52	0.55

X_9. Regulatory uncertainties of the waste processor	Yes															
X_{13}. Product description complexities	Yes								No							
X_{12}. Mixed waste received from the demolishers	Yes				No				Yes				No			
X_{14}. Human errors	Yes		No		Yes		No		Yes		No		Yes		No	
X_{15}. Health and safety concerns of the demolisher	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.75	0.72	0.70	0.67	0.54	0.48	0.48	0.42	0.57	0.53	0.50	0.46	0.48	0.45	0.35	0.10
No	0.25	0.28	0.30	0.33	0.46	0.52	0.52	0.58	0.43	0.47	0.50	0.54	0.52	0.55	0.65	0.90

Y. Quality assurance (QA) of the reverse logistics supply chains (RLSCs) of demolition waste (DW) - utility value

X_8. Workflow uncertainties of the demolisher	X_{16}. Workflow uncertainties of the waste processor	Y. QA in RLSC of DW (utility value)
Yes	Yes	0.00
	No	0.43
No	Yes	0.58
	No	0.99

Appendix 5(B): Case II - Summary of Conditional Probability Tables

X_1. Regulatory uncertainties of the demolisher

IPM_1. Rules and programs	Yes	No
Yes	0.35	0.83
No	0.65	0.17

X_2. Incentivizing uncertainties of the demolisher

X_1. Regulatory uncertainties of the demolisher	Yes		No	
IPM_3. Business partnering	Yes	No	Yes	No
Yes	0.90	0.95	0.15	0.4
No	0.10	0.05	0.85	0.6

X_3. Contractual uncertainties from forward supply chain-upstream actors

X_1. Regulatory uncertainties of the demolisher	Yes				No			
X2. Incentivizing uncertainties of the demolisher	Yes		No		Yes		No	
IPM_2. Planning and goal setting	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.58	0.92	0.52	0.84	0.16	0.51	0.15	0.35
No	0.42	0.08	0.48	0.16	0.84	0.49	0.85	0.65

X_4. Management of demolisher's sub-contractors

X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
IPM_{12}. Group meetings	Yes				No				Yes				No			
IPM_7. Performance evaluation of sub-contractors	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_9. Forming contracts	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.15	0.48	0.22	0.56	0.26	0.50	0.39	0.59	0.08	0.18	0.15	0.22	0.13	0.20	0.30	0.25
No	0.85	0.52	0.78	0.44	0.74	0.50	0.61	0.41	0.92	0.82	0.85	0.78	0.87	0.80	0.70	0.75

X_5. As-is condition of the building

X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
IPM_{13}. Hierarchical referral	Yes				No				Yes				No			
IPM_5. Site visits/ pre-demolition audits	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_4. Collection of building documents and asbestos registers	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.21	0.61	0.59	0.75	0.30	0.57	0.54	0.76	0.09	0.58	0.53	0.69	0.18	0.52	0.52	0.70
No	0.79	0.39	0.41	0.25	0.71	0.43	0.46	0.24	0.92	0.42	0.47	0.31	0.82	0.48	0.48	0.30

X_6. Management of contaminated/ hazardous substances

X_1. Regulatory uncertainties of the demolisher	Yes								No							
X_5. As-is condition of the building	Yes				No				Yes				No			
IPM_{11}. Investment in technologies	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{14}. Incorporation of self-contained groups	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.67	0.85	0.76	0.90	0.42	0.80	0.69	0.87	0.43	0.80	0.64	0.83	0.16	0.37	0.33	0.68
No	0.33	0.15	0.25	0.10	0.58	0.20	0.31	0.13	0.57	0.20	0.36	0.17	0.84	0.63	0.67	0.32

X_7. Health and safety concerns of the demolisher

X_6. Management of contaminated/ hazardous substances	Yes								No							
X_5. As-is condition of the building	Yes				No				Yes				No			
X_4. Management of demolisher's sub-contractors	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{15}. Creation of slack resources	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.62	0.82	0.61	0.82	0.51	0.76	0.52	0.76	0.56	0.75	0.55	0.75	0.44	0.61	0.42	0.51
No	0.38	0.18	0.39	0.18	0.48	0.24	0.48	0.24	0.44	0.25	0.45	0.25	0.45	0.39	0.57	0.49

X_8. Workflow uncertainties of the demolisher

X_1. Regulatory uncertainties of the demolisher	Yes															
X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
X_7. Health and safety concerns of the demolisher	Yes				No				Yes				No			
X_6. Management of contaminated/ hazardous substances	Yes		No		Yes		No		Yes		No		Yes		No	
X_4. Management of demolisher's sub-contractors	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.99	0.98	0.96	0.90	0.76	0.75	0.75	0.70	0.75	0.74	0.69	0.63	0.69	0.64	0.64	0.63
No	0.01	0.02	0.04	0.10	0.23	0.25	0.25	0.30	0.25	0.26	0.31	0.37	0.31	0.36	0.36	0.37

X_1. Regulatory uncertainties of the demolisher	No															
X_3. Contractual uncertainties from forward supply chain-upstream actors	Yes								No							
X_7. Health and safety concerns of the demolisher	Yes				No				Yes				No			
X_6. Management of contaminated/ hazardous substances	Yes		No		Yes		No		Yes		No		Yes		No	
X_4. Management of demolisher's sub-contractors	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.80	0.77	0.72	0.71	0.69	0.66	0.58	0.56	0.70	0.68	0.66	0.54	0.60	0.55	0.53	0.50
No	0.20	0.23	0.28	0.29	0.31	0.34	0.41	0.44	0.30	0.32	0.34	0.46	0.40	0.45	0.47	0.50

X_9. Regulatory uncertainties of the waste processor

IPM_1. Rules and programs	Yes	No
Yes	0.33	0.79
No	0.67	0.21

X_{10}. Incentivizing uncertainties of the waste processor

X_9. Regulatory uncertainties of the waste processor	Yes		No	
IPM_3. Business partnering	Yes	No	Yes	No
Yes	0.87	0.90	0.20	0.35
No	0.13	0.10	0.80	0.65

X_{11}. Contractual uncertainties from forward supply chain-downstream actors

X_9. Regulatory uncertainties of the waste processor	Yes				No			
X_{10}. Incentivizing uncertainties of the waste processor	Yes		No		Yes		No	
IPM_2. Planning and goal setting	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.60	0.95	0.52	0.89	0.33	0.58	0.31	0.32
No	0.40	0.05	0.48	0.11	0.67	0.42	0.87	0.68

X_{12}. Mixed waste received from the demolishers

X_8. Workflow uncertainties of the demolisher	Yes															
X_{14}. Human errors	Yes								No							
IPM_9. Forming contracts	Yes				No				Yes				No			
IPM_8. Waste acceptance criteria/ gate fees	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_6. Creation of integrator roles	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.40	0.61	0.85	0.86	0.62	0.66	0.88	0.95	0.39	0.59	0.84	0.86	0.60	0.65	0.86	0.93
No	0.60	0.39	0.15	0.14	0.38	0.34	0.12	0.05	0.61	0.41	0.16	0.14	0.40	0.35	0.14	0.07

X_8. Workflow uncertainties of the demolisher	Yes															
X_{14}. Human errors	Yes								No							
IPM_9. Forming contracts	Yes				No				Yes				No			
IPM_8. Waste acceptance criteria/ gate fees	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_6. Creation of integrator roles	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.35	0.36	0.50	0.53	0.39	0.43	0.59	0.79	0.10	0.30	0.42	0.47	0.33	0.37	0.53	0.73
No	0.65	0.64	0.50	0.47	0.61	0.57	0.41	0.21	0.90	0.70	0.58	0.53	0.67	0.63	0.47	0.27

X_{13}. Product description complexities

X_{11}. Contractual uncertainties from forward supply chain-downstream actors	Yes				No			
IPM_{12}. Group meetings	Yes		No		Yes		No	
IPM_{10}. Creation of special reports	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.45	0.79	0.56	0.89	0.40	0.69	0.50	0.75
No	0.55	0.21	0.44	0.11	0.60	0.31	0.50	0.25

X_{15}. Health and safety concerns of the waste processor

X_9. Regulatory uncertainties of the waste processor	Yes								No							
X_{12}. Mixed waste received from the demolishers	Yes				No				Yes				No			
X_{14}. Human errors	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{15}. Creation of slack resources	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.81	0.84	0.69	0.77	0.80	0.81	0.67	0.75	0.65	0.80	0.25	0.75	0.64	0.78	0.20	0.74
No	0.19	0.16	0.31	0.23	0.20	0.19	0.33	0.25	0.35	0.20	0.75	0.25	0.36	0.22	0.80	0.26

X_{14}. Human errors

X_{10}. Incentivizing uncertainties of the waste	Yes															
X_{13}. Product description complexities	Yes								No							
IPM_{14}. Incorporation of self-contained	Yes				No				Yes				No			
IPM_{13}. Hierarchical referral	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{11}. Investment of technologies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.65	0.58	0.72	0.70	0.93	0.91	0.78	0.74	0.48	0.16	0.63	0.10	0.73	0.14	0.72	0.65
No	0.35	0.42	0.28	0.30	0.07	0.08	0.22	0.26	0.52	0.84	0.37	0.90	0.27	0.86	0.28	0.35

X_{10}. Incentivizing uncertainties of the waste	Yes															
X_{13}. Product description complexities	Yes								No							
IPM_{14}. Incorporation of self-contained	Yes				No				Yes				No			
IPM_{13}. Hierarchical referral	Yes		No		Yes		No		Yes		No		Yes		No	
IPM_{11}. Investment of technologies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.75	0.66	0.72	0.69	0.80	0.75	0.83	0.76	0.51	0.09	0.65	0.58	0.72	0.66	0.73	0.67
No	0.25	0.34	0.28	0.33	0.20	0.26	0.17	0.24	0.48	0.91	0.35	0.42	0.28	0.34	0.27	0.33

X_{16}. Workflow uncertainties of the waste processor

X_9. Regulatory uncertainties of the waste processor	Yes															
X_{13}. Product description complexities	Yes								No							
X_{12}. Mixed waste received from the demolishers	Yes				No				Yes				No			
X_{14}. Human errors	Yes		No		Yes		No		Yes		No		Yes		No	
X_{15}. Health and safety concerns of the demolisher	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.99	0.93	0.89	0.88	0.75	0.72	0.72	0.65	0.81	0.79	0.77	0.76	0.52	0.50	0.50	0.48
No	0.01	0.07	011	0.12	0.25	0.28	0.28	0.35	0.19	0.21	0.23	0.24	0.48	0.50	0.50	0.52

X_9. Regulatory uncertainties of the waste processor	Yes															
X_{13}. Product description complexities	Yes								No							
X_{12}. Mixed waste received from the demolishers	Yes				No				Yes				No			
X_{14}. Human errors	Yes		No		Yes		No		Yes		No		Yes		No	
X_{15}. Health and safety concerns of the demolisher	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yes	0.77	0.72	0.73	0.69	0.55	0.49	0.48	0.44	0.58	0.54	0.51	0.47	0.49	0.45	0.36	0.11
No	0.23	0.28	0.27	0.31	0.45	0.51	0.52	0.56	0.41	0.46	0.49	0.52	0.51	0.55	0.64	0.89

Y. Quality assurance (QA) of the reverse logistics supply chains (RLSCs) of demolition waste (DW) - utility value

X_8. Workflow uncertainties of the demolisher	X_{16}. Workflow uncertainties of the waste processor	Y. QA in RLSC of DW (utility value)
Yes	Yes	0.00
	No	0.38
No	Yes	0.52
	No	0.91

Appendix 6: Statement of Authorship for Published Works

University of South Australia

Statement of Authorship

Title of Paper	Information sharing in reverse logistics supply chain of demolition waste: A systematic literature review
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021, 'Information sharing in reverse logistics supply chain of demolition waste: A systematic literature review', *Journal of Cleaner Production*, vol. 280, p. 124359.

PRINCIPAL AUTHOR		
Name of Principal Author (Candidate)	M.K.C.S. Wijewickrama	
Contribution to the Paper Brief description of your work in this publication	M.K.C.S. Wijewickrama is the greatest contributor to this publication. She conducted the study by reviewing the literature and analyzing and interpreting the findings. Furthermore, she drafted the research paper and did revisions based on the reviewer's comments.	
Overall Percentage (%)	50%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.	
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CO-AUTHOR CONTRIBUTIONS

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);

II. permission is granted for the candidate in include the publication in the thesis; and

III. the sum of all co-author contribution is equal to 100% less the candidate's stated contribution.

Name of Co-Author 1	Nicholas Chileshe	
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Name of Co-Author 2	Raufdeen Rameezdeen	

University of South Australia

% Contribution to the Paper	15%	
Signature *Signatures will be redacted by the Library at the time of publication*	[redacted]	Date 08/03/2023
Name of Co-Author 3	J.Jorge Ochoa	
% Contribution to the Paper	10%	
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University of South Australia

Statement of Authorship

Title of Paper	Quality assurance in reverse logistics supply chain of demolition waste: A systematic literature review
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021, 'Quality assurance in reverse logistics supply chain of demolition waste: A systematic literature review', *Waste Management & Research*, vol. 39, no. 1, pp. 3-24.

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Contribution to the Paper Brief description of your work in this publication	M.K.C.S. Wijewickrama is the greatest contributor to this publication. She conducted the study by reviewing the literature and analyzing and interpreting the findings. Furthermore, she drafted the research paper and did revisions based on the reviewer's comments.	
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University of South Australia

Statement of Authorship

Title of Paper	Minimizing macro-level uncertainties for quality assurance in reverse logistics supply chains of demolition waste
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2021, 'Minimizing macro-level uncertainties for quality assurance in reverse logistics supply chains of demolition waste', S*ustainability*, vol. 13, no. 23, p. 13069.

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University of South Australia

Statement of Authorship

Title of Paper	Information-centric influence strategies for quality assurance in reverse logistics supply chains: External stakeholders' perspective
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2022, 'Information-centric influence strategies for quality assurance in reverse logistics supply chains: External stakeholders' perspective', *Benchmarking: An International Journal*, vol. 29, no. 6, pp. 1857-1888.

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Contribution to the Paper Brief description of your work in this publication	M.K.C.S. Wijewickrama is the greatest contributor to this publication. She conducted the background study of the research, reviewed the literature and analyzed and interpreted the findings. Furthermore, she drafted the research paper and did revisions based on the reviewer's comments.	
Overall Percentage (%)	50%	
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University of South Australia

Statement of Authorship

Title of Paper	Information brokerage for circular economy in the construction industry: A systematic literature review
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Wijewickrama, MKCS, Rameezdeen, R & Chileshe, N 2021, 'Information brokerage for circular economy in the construction industry: A systematic literature review', *Journal of Cleaner Production*, vol. 313, p. 127938.

PRINCIPAL AUTHOR

Name of Principal Author (Candidate)	M.K.C.S. Wijewickrama	
Contribution to the Paper Brief description of your work in this publication	M.K.C.S. Wijewickrama is the greatest contributor to this publication. She conducted the study by reviewing the literature and analyzing and interpreting the findings. Furthermore, she drafted the research paper and did revisions based on the reviewer's comments.	
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Name of Co-Author 1	Raufdeen Rameezdeen	
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Statement of Authorship

Title of Paper	Information Processing for Quality Assurance in Reverse Logistics Supply Chains: An Organizational Information Processing Theory Perspective
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details Relevant reference details	Wijewickrama, MKCS, Chileshe, N, Rameezdeen, R & Ochoa, JJ 2022, 'Information Processing for Quality Assurance in Reverse Logistics Supply Chains: An Organizational Information Processing Theory Perspective', *Sustainability*, vol. 14, no. 9, p.5493.

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