High-rise Residential Buildings in Dhaka, Bangladesh: Strategies for Socially and Environmentally Sustainable Practice

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Table of Contents

List of Figures

List of Tables

List of Equations

List of Acronyms and Abbreviations

A21 SCDC	Agenda 21 for Sustainable Construction for Developing Countries
ANOVA	Analysis of variance
BBS	Bangladesh Bureau of Statistics
BEES	Building for Environmental and Economic Sustainability
BFSCDA	Bangladesh Fire Service and Civil Defence Authority
BILS	Bangladesh Institute of Labour Studies
BIP	Bangladesh Institute of Planners
BNBC	Bangladesh National Building Code
BREEAM	Building Research Establishment Environmental Assessment Methodology
CAB	Consumers Association of Bangladesh
CIB	International Council for Research and Innovation in Building and Construction
CCTV	Closed-circuit television
CUS	Centre for Urban Studies
DAP	Detailed Area Plan
DCC	Dhaka City Corporation
DESA	Dhaka Electric Supply Authority
DESCO	Dhaka Electric Supply Company Limited
DMDP	Dhaka Metropolitan Development Plan
DOA	Department of Architecture
DoE	Department of Environment
DTCB	Dhaka Transport Coordination Board

DWASA	Dhaka Water Supply & Sewerage Authority
FAP	Flood Action Plan
FAR	Floor Area Ratio
GDP	Gross Domestic Product
HBFC	House Building Finance Corporation
HBRI	Housing and Building Research Institute
IAB	Institute of Architects, Bangladesh
IEB	Institute of Engineers, Bangladesh
JICA	Japan International Cooperation Agency
JLN	Jurisdiction List Number
KGBCC	Korean Green Building Certification Criteria
LEED	Leadership in Energy and Environmental Design
LPG	Liquefied Petroleum Gas
LSD	Least Significant Difference
MOHPW	Ministry of Housing and Public Works
NEA	National Environmental Agency Singapore
NHA	National Housing Authority
OECD	Organisation for Economic Co-operation and Development
OUA	Other Urban Areas
PV	Photovoltaic
PVC	Polyvinyl chloride
PWD	Public Works Department
RAJUK	Rajdhani Unnayan Kartipakkha
REHAB	Real Estate & Housing Association of Bangladesh
RII	Relative Important Index
SBAT	Sustainable Building Assessment Tool

SBL	Sustainable Building Lifecycle
SD	Standard Deviation
SP	Structure Plan
SPSS	Statistical Package for the Social Sciences
STP	Strategic Transport Plan
TI	Town Improvement
TPSI	Tall-Building Projects Sustainability Indicator
UAP	Urban Area Plan
UDD	Department of Urban Development
UN	United Nations
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development
WFR	Window-to-floor area ratio
WHO	World Health Organization

Abstract

This research aims to develop strategies for socially and environmentally sustainable practice in high-rise residential buildings in Dhaka, Bangladesh. The ever-increasing demand for housing units in Dhaka is currently addressed by constructing high-rise residential buildings. More high-rise residential buildings can be expected to add to the plethora of the prevailing social and environmental problems, including pressure on utility services such as electricity, gas and water supply, lack of fire-fighting facilities, problems with solid waste disposal and non-conformance to building regulations.

The usefulness of the strategies for socially and environmentally sustainable practices for high-rise residential buildings in this research lies in a methodology that responds to the criteria set by building stakeholders and to the needs and perspectives of the specific users together with evidence on different aspects of living in high-rise residential buildings. Hence, this research has used an evidence-based research paradigm.

In this research, evidence was gathered through the application of quantitative and qualitative research methodology. The collection of data was conducted in four stages. In the first stage, socially and environmentally sustainable parameters for high-rise residential buildings that exist globally were identified through a literature survey. In the second stage, the criteria for achieving socially and environmentally sustainable practices for high-rise residential buildings were investigated through questionnaire surveys of more than 100 stakeholders, comprising of architects, planners, real estate developers, engineers and policy makers. In the third stage, the current social and environmental conditions, problems, constraints and achievements of the high-rise residential buildings in Dhaka were explored through questionnaire surveys of 117 residents in 30 high-rise residential buildings. In addition, data on the building design and construction as well as energy use records

of more than 300 apartments were collected. In the last stage, factors affecting electricity use in these residential buildings were investigated.

This research has formulated strategies for socially and environmentally sustainable practices for high-rise residential buildings for the following four stages: planning, design, construction and building operation. The strategies for socially sustainable practices developed in this research emphasise on adding value to the quality of life by focusing on maintaining culture and heritage, local employment, spatial design, maintenance and awareness and education; whereas, the strategies for environmental practices focus on proper site selection, reducing impact on ecology, adjacent properties and nearby water bodies together with improving the built environment, construction methods, building materials, waste management system and resource efficiency (with emphasis on occupant behaviour and household practices).

It should be noted that even though the strategies developed in this research are dispersed widely among a broad category of issues, the main emphasis has been on issues regarding spatial design, construction practice, resource management, maintenance and awareness and education. It is anticipated that the strategies developed in this research could be used as a guide to design, or policy to promote, sustainable high-rise residential buildings not only in Dhaka, but also in other cities worldwide, which face similar problems in terms of their demography and socio-cultural background as well as environmental problems and constraints.

Thesis Declaration

I, Tahmina Ahsan certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Tahmina Ahsan

Date: 30 May 2016

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Dedication

This thesis is lovingly dedicated to my father Syed Ahsanullah, whose last words to me, before slipping into a coma and subsequently death were to take up the PhD position "no matter what happens".

I have kept my promise dad………….

Section I: Background and Context

Chapter 1: Introduction

Chapter 2: Contextual Setting

Chapter 3: Literature Review

Chapter 4: Methodology and Methods

1 Introduction

1.1 Introductory Background

Bangladesh is small in geographical area, but one of the most densely populated countries in the world (UN 2014). In 2006, Dhaka, the capital of Bangladesh was ranked 11th among the world's megacities[1] with an estimated population of 12.4 million (UN 2006) and in 2014 Dhaka's population reached 16.9 million, placing it as the sixth most populated urban agglomeration (UN 2014). A prediction showed that by the year 2050, 56% of the population in Bangladesh would be living in urban areas (UN 2014) while Dhaka's population will grow to 27.4 million (UN 2014). The population density of Dhaka megacity increased between 2001 and 2011 from 7,055 to 10,484 persons per square kilometres (Corner & Dewan 2014). The annual population growth rate of Dhaka is projected to be 3.82% between the years 2014-2030 (UN 2014) and increasing urbanisation (Abdullah et al. 2014; Hafiz 2004) alongside rapid population growth has created an enormous pressure on the housing sector of Dhaka (Seraj & Islam 2013; Bhuiyan 2011; Alam & Ahmad 2011). Urbanisation has reached a critical point by surpassing the supply of infrastructure and services (Abdullah et.al 2014; Ahmed 2014; Ahmed 2011).

The total housing shortage in Bangladesh was estimated to be 5.0 million units by the end of the year 2000 (NHA 2015). According to Seraj and Islam (2013) every year, at least 100,000 new housing units are required in Dhaka to fulfil the growing housing demand. It should be added that the sum total of past years' deficits are

[1] UN (2003) defines a megacity as a metropolitan area (i.e. agglomeration) with a population of more than 10 million people. 'Agglomeration' usually allows for polycentric commuter

equivalent to the present requirement for housing, highlighting the already grave situation prevalent in the housing sector (Seraj 2012; Hafiz 2004).

The demand for vertical expansion in Dhaka has increased significantly in recent years as land is scarce and an increasing population, accompanied by urban migration, has increased the demand for housing (Alam & Ahmad 2011; Hussain 2010; Seraj and Alam 2009; Talukdar 2006; Rahman & Mowla 2003). High-rise residential has also gained popularity, as a horizontal expansion of Dhaka is not possible due to the following reasons: lack of buildable land within the city centre (Chowdhury & Faruqui 2009; Seraj & Alam 2009) and barriers such as the built up urban core and the low-lying flood plains (Alam 2014; Alam & Ahmad 2011; Roy 2009). It can thus be concluded that high-rise residential buildings must be the inevitable solution, to cater for the urgently needed housing units in densely packed urban areas.

Despite the growing popularity of high-rise residential buildings in Dhaka, these buildings are beset with various problems. Most high-rise residential buildings in Dhaka are unplanned (Khan 2012) and have been constructed by violating the building codes set by RAJUK[2] (Rajdhani Unnayan Kartipakkha or literally, the Capital Development Authority) and without regard to their physical, environmental, socio-cultural impacts on the overall city environment (Mourshed 2011; Iqbal 2005; Rahman & Mowla 2003; Hafiz 2000). The government of Bangladesh has acknowledged that about 90% of Dhaka's high-rise buildings do not even meet local construction standards (Hobson 2013).

The high-rise residential buildings create tremendous pressure on the demand for water supply and electricity (Hossain et al. 2013; Iqbal 2005; Khan 2012; Hafiz 2000) and they add extra pressure to the already debilitated urban services (Khan 2012; Iqbal 2005; Hafiz 2000).

[2] Rajdhani Unnayan Katripakkha is the regional planning organization for Dhaka responsible for planning, development and control of the 1528 km^2 area of Greater Dhaka

They are significantly responsible for the disappearance of open spaces and water bodies (Hafiz 2000). Mowla (2004) recommended that high-rise residential buildings must be built in a sustainable manner in order for the environment, economy and people to prosper. This is in line with the various concepts of sustainable building. The concept of sustainability has evolved since the emergence of sustainable development in the Brundtland Report (WCED 1987). Today, sustainable architecture aims to be environmentally aware, energy efficient and responsive to renewable materials and systems (Mendis 2013; Newman 2001). To put it simply, the concept of sustainable architecture consists of questions of a building's suitability for its socio-cultural as well as environmental context. (Williamson et al. 2003).

Given the problems concerning high-rise residential buildings, a business as usual approach of construction of high-rise residential buildings in Dhaka is anything but sustainable. At present, there is an absence of any kind of clear and verifiable measures for achieving sustainable high-rise residential buildings in Dhaka. The purpose of this research is to develop strategies to achieve socially and environmentally sustainable practices in high-rise residential buildings in Dhaka.

1.2 Problem Identification

The rapid growth of Dhaka's population is mainly caused by the heavy influx of migrants from the vast rural areas and other parts of the country (Nazem 2011; Hossain 2008). It is estimated that nearly 60% of the present population of the city are migrants who migrated to Dhaka for employment, education and other purposes (Seraj 2002). The average annual population growth rate of 4.1% in Dhaka between 1991 and 2001 surpassed the country's annual growth rate of 1.3% (BBS 2013 2008). If the present rate of population growth continues, Dhaka will surpass the size of Beijing by the year 2025, with an estimated population of 22.9 million (UN 2012).

1.2.1 Problem as a result of increasing urbanisation and rapid population growth

Figure 1-1 illustrates the relevance of the specific problems caused by increasing urbanisation and rapid population growth of Dhaka in accordance with this research. To begin with, Figure 1-1 depicts that increasing urbanisation, together with rapid population growth and limited horizontal expansion, owing to barriers such as the built up urban core and the low-lying flood plains (Roy 2009; Hossain 2008), has created huge pressure on the housing sector (Alam & Ahmed 2013; Kamruzzaman & Ogura 2007a; Khan 2006) of Dhaka. The present housing demand in Dhaka is not being fulfilled, without even considering projected future demands (Seraj and Islam 2013; Kamruzzaman & Ogura 2007b). The shortage in housing has led to the prevalence of some negative environmental consequences and inappropriate development practices in Dhaka as shown in Figure 1-1.

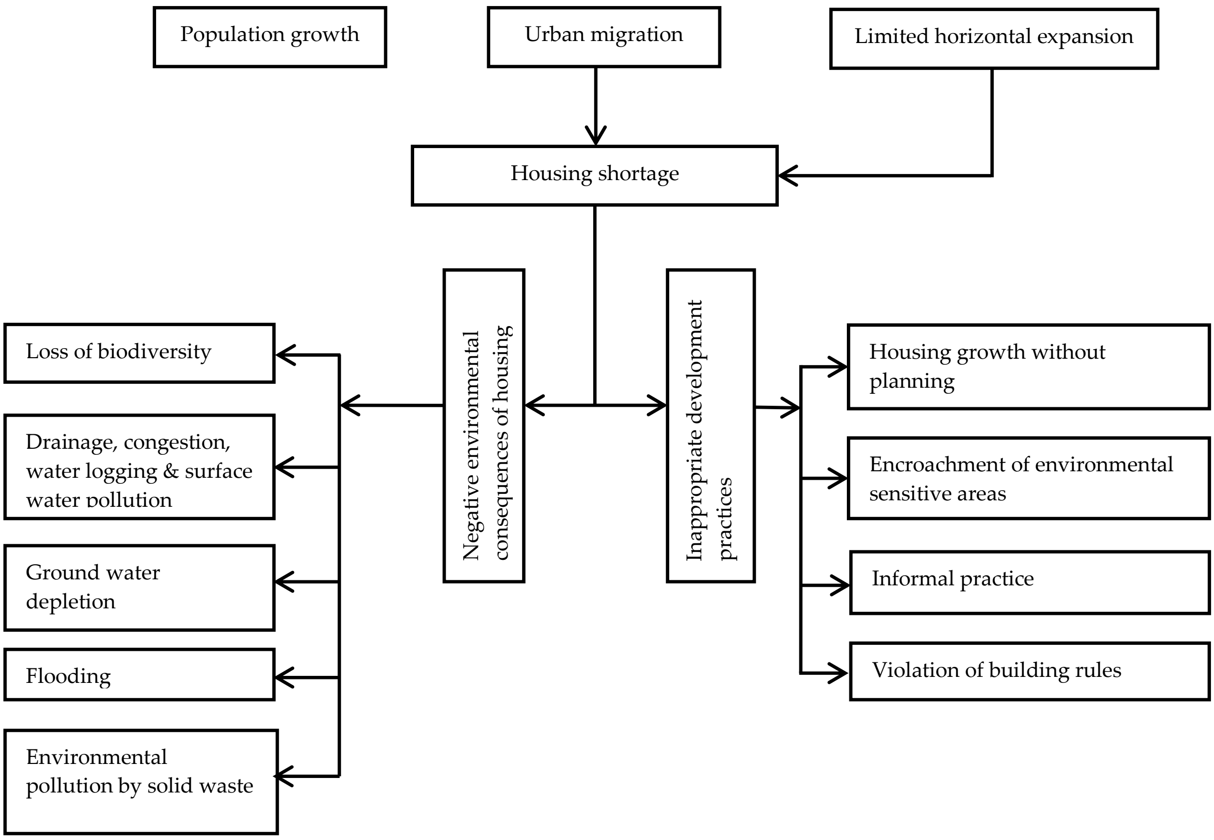


Figure 1-1 Housing situation in Dhaka

The shortage in housing has broadly led to five negative environmental consequences and four inappropriate development practices in Dhaka. The negative environmental consequences are discussed as follows:

1. Loss of biodiversity

Unplanned urbanisation and increasing population pressure create environmental degradation of the landscape and loss of biodiversity (Byomkesh et al. 2012). Encroachment on ecologically sensitive areas through unplanned housing built by individual landowners as well as private developers, along with the discharge of wastewater and solid waste into water bodies is responsible for the degradation of the landscape and associated loss of biodiversity (Nahrin 2012; Byomkesh et al. 2012).

2. Drainage, congestion, water logging and surface water pollution

According to Nahrin (2012), the aggregate effect of housing developments can considerably convert the topography that impacts the surface drainage system. Lack of appropriate drainage facilities, increased rainwater runoff from increased impervious areas, illegal encroachment and filling of natural drainage channels (Rana 2011; Alam & Ahmad 2010; Alam & Rabbani 2007) and garbage dumping (Nahrin 2012) are causing drainage systems to become congested and water logged. The drainage problems have become severe due to encroachment on to the wetlands by real estate developers (DWASA 2014). The surface water quality of canals, rivers, ponds and marshy lands is very poor in Dhaka due to untreated disposal of sanitary sewage and solid waste (Nahrin 2012).

3. Groundwater depletion

Unplanned construction of roads and housing developments has created huge impervious areas that do not allow absorption of rainwater (Mowla & Islam 2013; Rabbani 2009). Furthermore, encroachment on to water bodies, open space and the dumping of garbage in water bodies decreases the areas for rainwater recharge to underground aquifers (Nahrin 2012). In addition, over extraction of ground water for water supply in the city by the Dhaka Water and Sewerage Authority (DWASA) has resulted in lowering the ground water table (Dakua et al. 2013).

4. Flooding

Encroachment on to environmentally sensitive areas has resulted in a considerable increase in impermeable area, generating an obstacle to natural drainage pattern, and reduced retention basins, which has led to flooding in Dhaka (Alam 2014; Seraj & Islam 2013; Mowla & Islam 2013). The flooding in 2004 is thought to be the consequence of poor urban planning, together with the reclamation and development of natural areas, such as wetlands and low-lying areas (Dewan & Yamaguchi 2009b).

5. Environmental pollution by solid waste

Daily solid waste generation in Dhaka City Corporation (DCC) is about 3000-4000 tons (DCC 2012). About 40-50% of this waste is collected and disposed by the DCC and the rest remains uncollected or is disposed of illegally by residents into the vacant lands, low lands, street, canals and drains (Matter et al. 2013). Improper solid waste management causes environmental pollution effects (Matter et al. 2015) such as bad odour, degradation of air and soil quality, surface and ground water pollution, the creation of microbial breeding grounds, and the inducement and aggravation of health hazards (UNEP 2006).

The inappropriate development practices are discussed as follows:

1. Housing growth without planning

The pace of urbanisation in Dhaka has hindered the planning for housing due to the lack of adequate land use planning, development control and management. Constraints on available land have created a deficiency in integrated urban planning and housing, and weaknesses within institutions for urban management (Begum 2007). The already weak planning and development guidelines are disregarded by the private real estate developers (Alam & Ahmad 2013). Most housing projects in Dhaka have been developed illegally in the Dhaka Metropolitan Development Plan (DMDP) flood zone often without any planning approval (Alam & Ahmad 2013) and have also violated the high-value agricultural land policy (Alam 2011). Most of the residential areas have grown randomly with very high physical density, poor infrastructure and congested streets (Alam & Ahmad 2010; Alam & Rabbani 2007; Buckley & Kalarickal 2006; Islam 2009).

2. Encroachment upon environmentally sensitive areas

Due to rapid population growth, high land prices and socio-economic development, encroachment upon open space, vegetation, peripheral agricultural land, wetlands, fallow land and water bodies is becoming a common practice among real estate developers in Dhaka (Dewan et al. 2012; Begum 2007). Most of the natural drainages of Dhaka have already vanished or are on the verge of becoming non-existent due to encroachment through the unplanned development and unauthorised land filling to develop new residential areas (Seraj & Islam 2013; Tawhid 2004). Encroachment on to suburban and agricultural land for the outward expansion of the city is not only carried out by real estate developers, but also supported by government policy in the Dhaka Metropolitan Development Plan (DMDP) 1995-2015 (Zaman et al. 2000).

3. Violation of building codes

Even though there are planning laws and building regulations to control overall urban development, these laws and regulations are not specifically effective in controlling building development (Zaman et al. 2000). The ineffectiveness of the laws and building regulations can be attributed to the numerous administrative loopholes that allow malpractice, together with the lack of strict monitoring of the implementation of the regulations (Zaman et al. 2000). According to Alam and Ahmad (2013) high-profile corruption is also widespread and for this reason, rules and regulations are frequently violated, particularly those under the jurisdiction of RAJUK, leading to a poor living environment in the housing projects. In fact, most of the buildings in Dhaka have been built without having the required permission from RAJUK (Nahrin 2012) and about 90% of the buildings have violated the mandatory height limitations of the Building Construction Rules (BCR) 1996 (Mahmud 2007a). At present, public developers like RAJUK and the National Housing Authority (NHA) are also filling in existing retention ponds in Dhaka city, violating the DMDP law (Alam 2014). The buildings permitted by RAJUK may also encroach upon the approved plan by increasing the built-up area within the plot, increasing the total floor area or height of the building (Nahrin 2012). Transformations of the uses of buildings, such as changing residential to commercial or institutional without any consent are common courses of action in Dhaka. Around 94% buildings in Dhaka have somehow violated the 'Building Construction Rules (BCR), 1996' or diverged from the permitted plan (Mahmud 2007a). The Building Construction Rules 1996 (prior to the development and enactment of the Building Construction Rules 2006) permitted the construction of buildings covering 70% to 80% of the plot area through the provision of setback rules (Nahrin 2012). However, the setback or uncovered space of the plots has been usually paved for other usage, leaving no space for the access of services such as fire-fighting facilities.

4. Informal practice

The large rural–urban migration has caused a hasty rise in the number of slums (Rana 2011; Angeles et al. 2009; Islam 2005a). The increasing rates of urban migration also make it difficult to provide housing with public facilities such as transportation, water, sewerage, drainage and electricity services (Sinthia 2013). Owing to the unplanned development of the city, the service providing authorities are usually unable to install sufficient utility services to all neighbourhoods (Nahrin 2012). As a result, informal practices have been established among the residents. For instance, even though the Building Construction Rules 2006 suggested constructing individual septic tanks in areas where there is no sewerage network, the illegal practice is to link up the sewer water source, as well as septic tanks, to the roadside storm water drains as it is expensive to construct and clean septic tanks (Nahrin 2012). Another example of an informal practice is the dumping of household waste by residents on vacant land, low lands, streets and in canals, as the DCC (Dhaka City Corporation) does not have proper collection points for household waste.

1.2.2 The specific condition of current high-rise residential buildings in Dhaka

One response to the problems of increasing urbanisation and rapid population is building high-rise residential buildings; however, majority of the high-rise residential buildings in Dhaka are not planned (Khan 2012; Haq 2007) and have been built disregarding building codes set by the RAJUK and neglect their physical, environmental and socio-cultural effects on the overall city environment (Haq 2007; Iqbal 2005; Rahman & Mowla 2003; Hafiz 2000) and they also contribute considerably to the disappearance of open spaces and water bodies (Dewan et al. 2012).

As these high-rise residential buildings do not follow setback rules (the rules restricting the buildings to follow the mandatory setback distance from roads), there is inadequate distance between the buildings (Hussain 2010; Shafi 2010) and so many buildings adjacent to these high-rise residential buildings are deprived of adequate daylight and airflow (Khan 2012), thus forcing the occupants to rely on mechanical cooling and artificial lighting. Furthermore, these high-rise residential buildings cause problems on adjacent roads that have not been modified to cope with the extra traffic from their residents leading to congestion during traffic rush hours (Iqbal 2005; Mowla 2004; Hafiz 2000).

Haq (2007) asserts that many of the high-rise residential buildings have been constructed without ensuring adequate structural strength and addressing proper safety measures. The architectural and structural designs, construction and safety requirements of high-rise residential buildings in Dhaka are not monitored, and as a result, since the high-rise residential buildings are sometimes built on filled land, they can face sudden structural collapse even without the occurrence of an earthquake (Mahmud 2011). Further, experts say that about 80% of high-rise buildings face the risks of fire hazard and earthquake (Mahmud 2011). Dhaka is not appropriately prepared for earthquakes because of its unplanned urbanisation and disregard of the national building code (Mahmood 2012; Paul & Bhuiyan 2010). Haq (2007) adds that many of the high-rise buildings are built disregarding the land use plan and such improper use of land makes these buildings susceptible to earthquakes. Fire hazard susceptibility has increased in Dhaka due to uncontrolled building construction and non-compliance with building codes, planning rules and fire protection acts (Islam & Adri 2008), and so fire safety is not sufficiently addressed in high-rise buildings (Islam & Adri 2008; Haq 2007; Iqbal 2005).

Hussain (2010), Munni (2010), Razzaque and Nahid (2007) and Iqbal (2005) emphasise that high-rise residential buildings lack recreational, community and open spaces for social interaction. Most high-rise buildings do not provide playing space for children (Hussain 2010; Munni 2010; Shafi 2010; Razzaque & Nahid 2007).

According to Hussain (2010), problems related to design in high-rise residential buildings include inadequate distance between buildings, which negatively impacts visual privacy (Khan 2012), lack of green spaces, playing areas, fire escapes and community spaces, inefficient natural ventilation, small sized rooms, inadequate daylight, dampness, narrow stairs and inconvenient corridors. He also adds that there is frustration among the owners due to frequent use of low quality construction and fitting materials, defects in construction processes leading to cracks in floors and walls, dampness in walls and excessive heat on the top floors.

According to Khan (2012), Iqbal (2005), Rahman and Mowla (2003) and Hafiz (2000), high-rise residential buildings create tremendous pressure on the water supply system as these high-rises use heavy pumps, connected to the supply mains, to extract extra volumes of water to be used by the residents, thereby creating a water crisis for the neighbouring buildings.

As already mentioned, high-rise residential buildings create pressure on the demand for electricity to the already power shortage in Dhaka that does not meet growing needs. This shortage of power supply reaches its peak during the summer months when there are alternate hours of load shedding. As the dwellers of the high-rise residential buildings are mainly the wealthy and affluent class of society (Khan 2012), the increased demand for electricity is due to their increased standard of living (Unnayan Shamannay 2006) resulting in increased use of air conditioners (Khan 2012; Hancock 2006), water heaters, ovens and other electronic equipment (Khan 2012).

The use of electricity in high-rise housing is more than in low-rise buildings due to the use of elevators and the need to run water pumps to supply water to higher levels (Iqbal 2005; Hafiz 2000; Khan 2012). A significant number of these high-rise buildings are equipped with generators to run elevators, supply power and keep water supplies running (Hafiz 2000). The generators raise housing costs, contribute to air pollution and cause sound pollution (Hafiz 2000).

In response to the development of high-rise residential buildings, the demand for brick has increased and this has led to increasing numbers of fired brick kilns. In order to reduce transportation costs, these are often constructed close to the city and near riverbanks (Hafiz 2000). These brick kilns are a source of air pollution as the vast majority of the brick kilns are coal fired, hence are energy-intensive and highly polluting.

As only 20% of Dhaka's population are connected to a conventional sewer network (Aus Health International 2008), most sewage discharge in Dhaka is not treated and dumped directly into the water bodies. As many buildings, with the inclusion of high-rise residential buildings, do not have proper waste management systems, their effluent is discharged directly into lakes, canals and rivers, giving rise to pollution and hygienic hazards (AusHealth International 2008). In Dhaka, waste collection and disposal was privatised by the Dhaka City Corporation and households are required to pay for the door-to-door collection and disposal of waste

(Afroz et al. 2009). Inefficient monitoring and co-ordination results in solid waste being dumped in open spaces on public roadsides by sub-contractors. The government authority then collects the waste from the roadsides and disposes it in landfills. However, as the waste is not collected from the roadsides regularly, the areas around these waste sites contribute to air pollution (Afroz et al. 2009).

The current scenario of high-rise housing in Dhaka can therefore be summarised in two categories: social and environmental. The social issues consist of problems relating to spatial design impacting the relationship of the occupants to each other and to the built environment, whereas the environmental issues consist of problems regarding the built environment, construction practice, ecological impact, impacts on water bodies, impacts on air, resource management and waste management as presented in Table 1-1.

Table 1-1: Key problems identified in high-rise residential buildings in Dhaka

Key problems identified in high-rise residential buildings in Dhaka	
Social issues	**1. Spatial design**
	Inadequate distance between the buildings negatively impacting visual privacy
	Lacking recreational and community space
	Lacking open spaces for social interaction
	Lacking playing space for children
	Small sized rooms
Environmental issues	**1. Built environment**
	Inefficient natural ventilation
	Inadequate daylight
	2. Construction practice
	Violation of building codes
	Lacking adequate structural strength
	Proper safety measures not addressed
	Uncontrolled architectural and structural designs
	Unmonitored safety requirements
	Risks of fire hazard
	Risks of earthquake
	Uncontrolled building construction practices
	Low quality construction and fitting materials
	Defects in construction processes
	2. Ecological impact
	Open space is not conserved
	Water bodies are not conserved
	3. Impact on water bodies

Key problems identified in high-rise residential buildings in Dhaka	
	Brick kilns constructed near river banks cause damage to water bodies
	4. Impact on air
	Air pollution during construction
	5. Resource management
	Tremendous pressure on the water supply system
	Tremendous pressure on the demand for electricity
	6. Waste management
	Lack of proper waste management systems

1 . 3 Research Focus and Delimitations

1.3.1 Research Focus

In this research, high-rise residential buildings are defined as buildings that are seven storeys or more. This research focuses on high-rise residential buildings in Dhaka owing to the fact that the ever-increasing demand for housing units in Dhaka is addressed by constructing high-rise residential buildings. Statistics for high-rise buildings in Dhaka for 2010 show that the majority (about 31%) of the high-rise buildings are used for residential purposes, whereas, about 30% are used for commercial, 18% for mixed-use, 12% for institutional and 9% for industrial purposes (HBRI & CUS 2010). Consequently, high-rise residential buildings can be expected to grow in number and add to the plethora of prevailing problems they cause. Prevalent problems in high-rise residential buildings in Dhaka include pressure on utility services such as electricity, gas and water supply, fire-fighting, solid waste disposal, non-abidance to building regulations, lack of visual privacy due to inappropriate setback distances between buildings and traffic congestions. It is therefore crucial that the high-rise residential buildings are built in a socially and environmentally sustainable way.

1.3.2 Delimitations

It is worth noting that this research delimits the economic aspects of developing high-rise residential buildings as data on the construction costs of high-rise residential buildings in Dhaka were very difficult to obtain from real estate developers, architects or construction engineers due to the profit mechanisms employed. Data on building operational costs were also not available. The only data on costs that were available for analysis in this research were on rent of the apartments, energy costs (for electricity use in apartments) and utility costs for various services such as elevators, generators, common lighting in stairs, household waste collection and security.

1.4 Research Aim

This research aims to develop strategies for socially and environmentally sustainable practice in high-rise residential buildings of Dhaka. Whilst the research focuses on Dhaka, the research is expected to also contribute to other cities, which face similar problems as Dhaka in terms of their demography and socio-cultural background, as well as environmental problems and constraints.

1.5 Research Questions and Objectives

The following research questions and objectives have been encompassed to achieve the aim outlined:

1. What are the parameters for socially and environmentally sustainable high-rise residential buildings that exist globally, and what are the present initiatives and efforts for achieving socially and environmentally sustainable high-rise residential buildings in Dhaka?

2. What, according to the stakeholders, are the criteria for achieving socially and environmentally sustainable practices for high-rise residential buildings?

3. What are the current conditions, problems, constraints and achievements of high-rise residential buildings in Dhaka, Bangladesh?

> *Objective 1: To investigate the perceptions of the occupants regarding the height of high-rise residential buildings.*

Objective 2: To examine the social and environmental conditions in high-rise residential buildings.

Objective 3: To identify the importance of the recommended neighbourhood facilities.

Objective 4: To identify the factors that need improvement for increasing satisfaction in high-rise living.

Objective 5: To identify the concerns regarding high-rise living.

Objective 6: To explore the behavioural responses of the occupants of high-rise residential buildings in regards to social and environmental issues of living in high-rise residential buildings.

4. What are the factors that affect energy use in high-rise apartments?

Objective 7: To determine the electricity use of the apartments in high-rise residential buildings.

Objective 8: To explore the influence of temperature, relative humidity and wind speed on electricity use.

Objective 9: To identify the design and household characteristics that influence electricity use.

Objective 10: To explore the household practices that influence electricity use.

5. What are the strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka?

1.6 Significance of the Research

This thesis accepts the status quo of high-rise buildings, as they currently exist, as being the primary source from which to glean insights for sustainable practice. It is anticipated that the strategies developed in this study could potentially be used as a guide to design or policy to promote socially and environmentally sustainable high-rise residential buildings not only in Dhaka, but also in other cities worldwide, which face similar problems in terms of their demography and socio-cultural background, as well as environmental problems and constraints. Furthermore, the strategies outlined in this research could also be adopted in other cities of Bangladesh where there is a trend for high-rise residential buildings.

1.7 Research Methodology

There is no "one size fits all" approach to socially and environmentally sustainable practices for high-rise residential buildings. The usefulness of the strategies for socially and environmentally sustainable practices for high-rise residential buildings in this research lies in a methodology that would respond to the criteria set by building stakeholders and respond to the needs and perspectives of the specific users, together with evidences based on the different aspects of living in high-rise residential buildings. Hence, this research has used an evidence-based research paradigm.

A critical feature of this methodology has been the centrality of evidence-based on findings from the stakeholder questionnaire survey, household questionnaire survey and design characteristics, household characteristics and household practices affecting electricity use. In this research, evidence was gathered through the application of mostly quantitative and limited use of qualitative research methodology. The quantitative methodology, involving collection of data through questionnaire survey and field survey, clearly identified existing issues relating to planning, design, construction and building operation.

The evidence gathered through quantitative data collections was analysed quantitatively using statistical methods. The methodology engaged in this research consist of six main steps as explained in Figure 1-2 and outlined below. Detailed explanations of the research methodology are provided in Chapter 4.

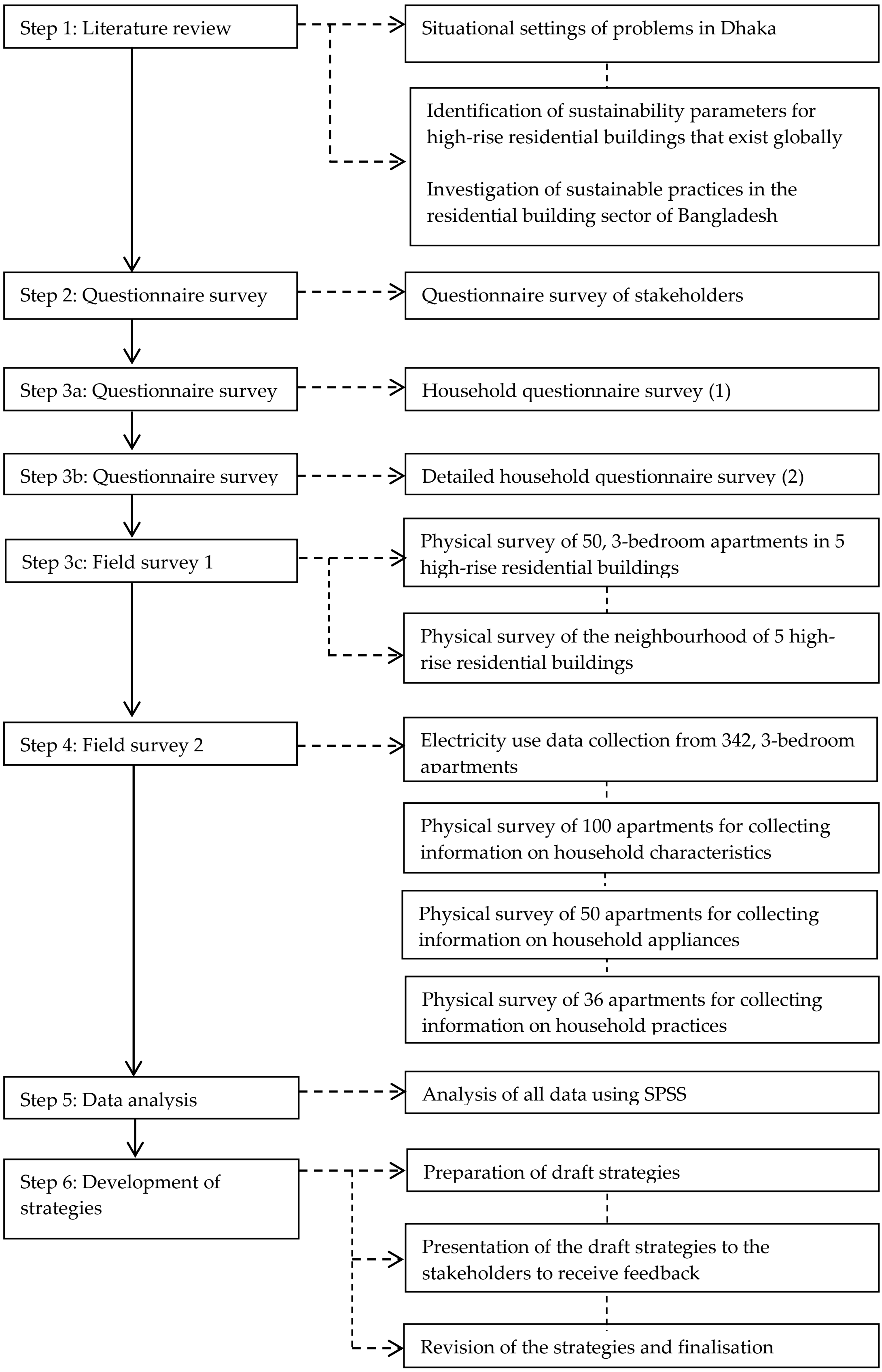


Figure 1-2: Six steps of research methodology employed

1. Step 1

Step 1 was designed to provide the answers to the first research question. It involved a literature review in two stages. In the first stage, literature, statistical data, reports from various organisations, other relevant studies and data from various policy documents were reviewed to document the social and environmental living conditions in Dhaka. This step identified and compiled the present problems faced by people residing in Dhaka. The second stage involved a literature review to evaluate the key concepts of sustainable construction, to identify the sustainability parameters for high-rise residential buildings that exist globally and their potential application to high-rise buildings in Dhaka. The findings from this step, thus justified the necessity and suitability of the issues and parameters for the identification of sustainability in high-rise residential buildings in the context of Dhaka. The literature review was also used to investigate the local conditions and constraints in the residential building sector in Dhaka. This also included an analysis of any recent relevant initiatives and legislation or regulations that promote sustainable practices in the residential building sector of Bangladesh.

2. Step 2

Step 2 provided the answers to the second research question. This step investigated how stakeholders viewed sustainability in high-rise residential buildings through a questionnaire survey. The stakeholders comprised of planners, architects, real estate developers, engineers and policy makers seeking to identify the criteria to achieve socially and environmentally sustainable high-rise residential buildings.

3. Step 3

Step 3 was designed to provide the answers to the third research question. Step 3 involved two surveys of households through questionnaires and a field survey to investigate the present scenario of high-rise residential buildings in Dhaka. The questionnaire survey included both open and close-ended questions. The field survey involved a physical survey of high-rise residential buildings to achieve the following: identify the design characteristics of the apartments, measure the day-lighting and noise in various rooms of the apartments, measure the setback distance on all sides of the buildings and calculate the effective canyon ratio around the five case study buildings. A physical survey of the neighbourhood facilities around the case study buildings was also conducted.

4. Step 4

Step 4 was designed to provide answers to research question 4. This involved electricity use data collection for one year from the case high-rise apartments. The occupants of these apartments were contacted again to obtain further information on household characteristics, household appliances and household practices. This step helped identify the factors that affect electricity use in response to the fourth research question.

5. Step 5

Step 5 analysed all the data collected in steps 2, 3 and 4 to develop draft strategies for socially and environmentally sustainable practices to formulate the final strategies for socially and environmentally sustainable practices. The data were analysed using various statistical methods in SPSS.

6. Step 6

Step 6 provided answers to research question 5 (the last research question). This step involved the development of draft strategies for socially and environmentally sustainable practices, leading to the presentation of these draft strategies to the stakeholders concerned for their feedback. The feedbacks from the stakeholders were then incorporated in formulating the final strategies for socially and environmentally sustainable practices.

1.8 Thesis Structure

This thesis is structured as follows:

Section I: Background and Context

Chapter 2: Contextual setting

This chapter situates the research within the contextual settings of Dhaka. It does this by providing information on the physical settings and growth of Dhaka, and by examining the social and environmental problems of the city. The chapter highlights the state of governance for housing/development control and the infrastructure services in Dhaka, with particular emphasis on the trend of high-rise apartment living, together with the constraints and priorities that outline the specific criteria that need to be investigated to develop strategies for socially and environmentally sustainable practice in high-rise residential buildings.

Chapter 3: Literature review

This chapter provides a theoretical basis for this research by reviewing literature on the key aspects of sustainable construction, sustainable building, sustainable high-rise building and sustainable high-rise residential buildings worldwide. In order to address the gap in the literature for sustainable high-rise residential buildings for the context of Dhaka, this chapter also presents the progress in Dhaka, if any, in terms of promoting sustainable high-rise residential buildings.

Chapter 4: Methodology and Methods

This chapter situates this research within the specified methodological approach of evidence-based research and provides a rationale for that approach and describes the research methods, sampling process, data collection and analysis methods used. The chapter also provides a detailed description of all aspects of the research design and procedures carried out.

Section II: Results and Analysis

Chapter 5: Views of stakeholders

This chapter quantitatively explores the stakeholders' understanding of sustainable high-rise residential buildings at different stages, and the preferences and criteria for socially and environmentally sustainable high-rise residential buildings in Dhaka. This was done by analysing quantitative data based on a stakeholder questionnaire survey. The findings of this chapter have been included in formulating strategies for socially and environmentally sustainable high-rise residential buildings in Chapter 8.

Chapter 6: High-rise living in Dhaka

This chapter explores the social and environmental aspects of living in high-rise residential buildings in Dhaka, together with the satisfaction and concerns of high-rise living. It also investigates behavioural aspects of occupants regarding the social and environmental aspects of high-rise living. This was done by analysing quantitative data based on household questionnaire surveys. The findings of this chapter have been included in formulating strategies for socially and environmentally sustainable high-rise residential buildings in Chapter 8.

Chapter 7: Electricity use in high-rise apartments

This chapter examines the influence of external conditions, design characteristics and household characteristics on total annual electricity use in the case study high-rise residential buildings in Dhaka. In addition, this chapter also explores the effect of household characteristics and household practices on total annual cooling and air-conditioning electricity use. The findings of this chapter have been included in formulating strategies for socially and environmentally sustainable high-rise residential buildings in Chapter 8.

Section III: Recommendations and Conclusion

Chapter 8: Strategies for socially and environmentally sustainable practices

This chapter presents the final outcome of this thesis: the strategies for socially and environmentally sustainable practices based on the findings in Chapters 5, 6 and 7. Chapter 5, 6 and 7 addresses the second, third and fourth research questions respectively, and the answers to these three research questions lie at the core of developing the strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka.

Chapter 9: Conclusion

This chapter summarises the findings in this research and states the conclusions based on an integration of the research findings, analysis, interpretation, and synthesis. Limitations of this research and conditional statements are made with respect to the application of the proposed strategies. In addition, recommendations for further research are suggested towards the end of this chapter.

2 Contextual Settings

2.1 Introduction

This chapter aims to place the research within the contextual settings of Dhaka and it draws on existing literature and relevant documents, including government reports. While Chapter 1 has briefly discussed the problems in Dhaka, this chapter will discuss the problems in detail to provide clear contextual settings for this research. The chapter is divided into seven sections. The first and second sections describe the physical settings, growth, and the climate of Dhaka, while the third, fourth and fifth sections examine the social, environmental problems and natural and human induced hazards. In the sixth and seventh sections, the chapter highlights the state of the governance for housing/development control and infrastructure services in Dhaka, with particular emphasis on the social and environmental problems and prospects for apartment living. This is to identify the issues that are of importance in the construction of high-rise residential buildings, which could be studied further to explore whether they contribute to achieving sustainable high-rise residential buildings.

2.2 Physical settings and growth of Dhaka

Dhaka, the capital of Bangladesh, one of the largest megacities of the world, has existed as the largest city in the region for approximately 400 years, dating back from the seventeenth century (Chowdhury 2013). Over these 400 years, the city has faced a number of dramatic historical changes in terms of politics, demographic and topographic structure from its beginning (Rabbani 2009). The growth of the city has been dictated by natural forces, rather than by any comprehensive planning

(Chowdhury 2013). Based on available literature and documents, the growth and changing pattern of Dhaka can be divided into the following five different phases as depicted in Figure 2-1(Chowdhury & Faruqui 2009; Talukder 2006; UNEP 2006; Banglapedia 2006):

- Phase 1: Pre-Mughal period (before 1608);
- Phase 2: Mughal Period (1608-1764);
- Phase 3: British Period (1764-1947);
- Phase 4: Pakistan Period (1947-1971); and
- Phase 5: Bangladesh Period (1971-onwards)

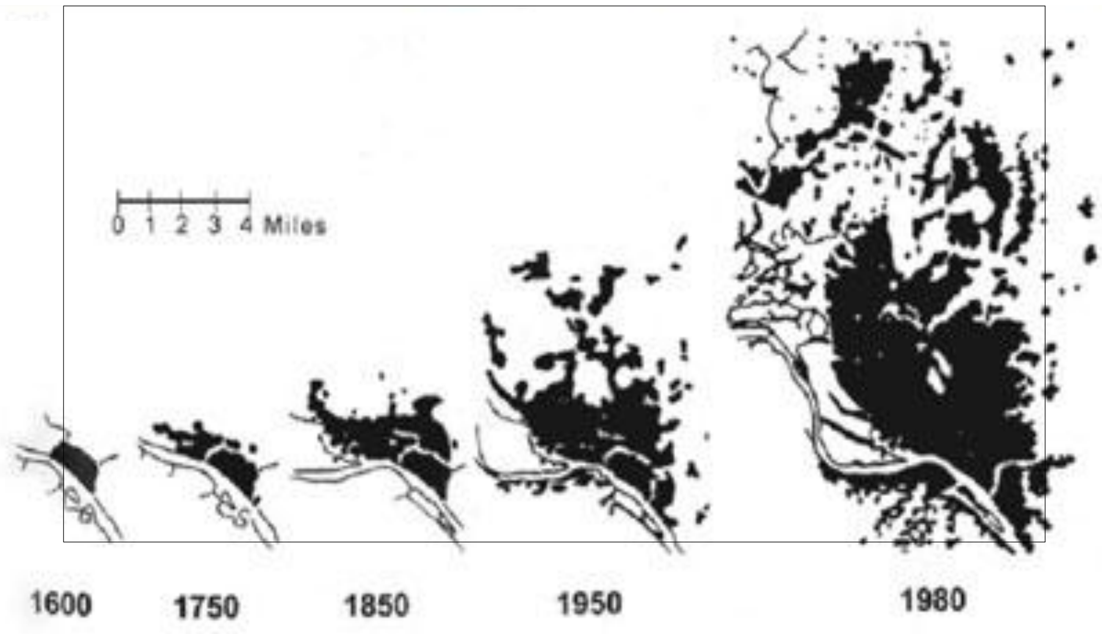


Figure 2-1: Historical Growth of Dhaka

Source: Shankland Cox Partnership (1981)

1 mile= 1.61 kilometres

Among the different area connotations of “Dhaka City”, in this research the spatial extent of Dhaka city consists of Dhaka megacity with an area of 1,371 square kilometres (BBS 2008). The geographical extent of Dhaka megacity is between 23.55°and 24.18°N latitudes and 90.18°and 90.57°E longitudes (Corner & Dewan 2014). At present, the megacity includes six municipalities (Kadamrasul, Gazipur, Narayanganj, Siddirganj Savar and Tongi, the entire area of Dhaka City Cooperation (DCC) and 68 adjacent unions[3] that are characterised as "other urban areas" (OUA) (Corner & Dewan 2014). Five major river systems flow across the megacity (Corner & Dewan 2014). Topographically, the area is flat with a surface elevation ranging from 1 to 14 meters above the mean sea level, with most urban areas situated at elevations that range from 6 to 8 metres (FAP 8A 1991). The main geomorphic units are the highlands (Dhaka Terrace), the lowlands or floodplains, the depressions and the abandoned channels (Miah & Bazlee 1968 cited in Corner & Dewan 2014). A principal feature of Dhaka and its neighbouring areas is the low-lying areas and low proportion of highland that is free from inundations during annual floods (Alam & Ahmad 2011). Other major geomorphic features include the low-lying swamps and marshes situated in and around the city (Corner & Dewan 2014). These low-lying swamps and marshes, with potential threats of flooding, are considered to be significant barriers to the physical expansion of the city (Alam & Ahmad 2011).

The population and physical expansion of the megacity for a period of 60 years is shown in Table 2-1. It is evident from Table 2-1 that since 1951the population has increased 35 times, while the area of the city has expanded approximately 16 times. The growth of Dhaka has been random, with the topography of the area dictating the terms and conditions of the growth (Talukder 2006). Dhaka is now facing changes in its urban character, with vertical development substituting horizontal expansion as vacant high land in the bioregion is filled up (Talukder 2006). In order to manage the ever-increasing population pressure, the city has started to expand vertically (Talukder 2006).

[3] Union is a rural administrative geographic unit consisting of one or more "mauzas"and villages governed by Union Parishad Institution (Dewan & Corner 2014). Mauza is the smallest rural geographic revenue unit that has a Jurisdiction List Number (JLN) (Dewan & Corner 2014).

Table 2-1: Population of Dhaka Megacity

Year	Population	Area (km^2)
1951	411,279	85
1961	718,766	124
1974	2,068,353	336
1981	3,440,147	402
1991	6,487,459	1353
2001	9,672,763	1371
2011*	14,509,100	1383

*Derived from BBS community series 2012, Source: BBS (1998, 2001, 2008)

2.3 Climate of Dhaka

The climate of Dhaka can be categorised as Aw or tropical wet and dry according to the Koppen–Geiger climate classification (Kottek et al. 2006) and is characterised by three distinct seasons (Corner & Dewan 2014; Mourshed 2011; Talukder 2006):

- A hot summer season from March to June with high temperatures between 28 and 34°C, a high rate of evaporation and erratic heavy rainfall;
- A hot and humid monsoon season from June to October with torrential rainfall, accounting for about two thirds of the annual rainfall; and
- A cooler and drier winter season from November to March with temperatures between 10 and 21°C and little rainfall.

2.4 Social problems of Dhaka megacity

Dhaka megacity is characterised by extreme inequality and poverty (Siddiqui et al. 2010; Begum 2007; Hossain 2006; Islam 2005a, b). Although the incidence of poverty in Dhaka has, to some extent waned over time (BBS 2011; Hossain 2006), the percentage of urban poor in Dhaka is still as high as 45%, of which 25% are categorised as very poor (CARE 2007 cited in Sanderson 2012). The rich people in Dhaka, who enjoy high standards of living, make up only 3% of the total population, whilst the remaining are in the middle and lower income groups (Hossain 2006).

The literacy rate is increasing gradually and according to the population and housing census of 2011, the male literacy rate of 70% was higher compared to the female literacy rate of 63% (BBS 2012).

As the growth of Dhaka is exceeding its economic development, the large rural–urban migration, mainly by marginalised rural people, has contributed to the rapid growth of slum population (Rana 2011; Angeles et al. 2009; Islam 2005a). According to Corner and Dewan (2014), the slum population in Dhaka has increased more than two folds in the past decade, reaching about 3.4 million in 2005. The number of slums augmented by approximately 70% during the same period (CUS et al. 2006) and the population density of the slums are greater compared to the non-slum urban areas (Sanderson 2012).

As a result of high population density, extreme inequality in the distribution of resources and the inadequacy of the law enforcement agencies, the law and order situation of Dhaka is declining at a frightening rate (Siddiqui et al. 2010; Islam 2005b). People constantly feel threat to life and property, while crimes go unpunished (Ali 2002). A study by Siddiqui et al. (2010) shows that about 60% of all crimes in the country is committed in Dhaka. The study further shows that criminal offenses, including robbery, violence against women, murder, child abuse, kidnapping and smuggling have increased by 61% during the twenty-year period from 1985 and 2005. In addition to these crimes, political violence also takes place in the form of clashes, particularly during processions, demonstrations and political meetings, between the police and opposition political groups or between supporters of the government and opposition political parties (Hossain 2006).

2.5 Environmental problems

The major environmental problems in Dhaka constitute air pollution (Corner & Dewan 2014; Rana 2011; Rabbani 2009) and sound pollution (Rana 2011; Rabbani 2009), water contamination (Corner & Dewan 2014; Rabbani 2009), groundwater declination (Rabbani 2009), solid waste mismanagement (Corner & Dewan 2014; Rana

2011; Rabbani 2009), lack of sewage management (Rabbani 2009), decreasing number of wetlands (Rana 2011) and loss of biodiversity (Rana 2011). The sections below provide a brief overview of each of the problems mentioned.

2.5.1 Air pollution

The level of air pollution in Dhaka is severe and getting worse (Begum et al. 2010; BBS 2010). The two major sources of air pollution are vehicular emissions (Rana 2011; Rabbani 2009) and industrial emissions (Begum et al. 2011; Rana 2011; Rabbani 2009; Hasan & Mulamoottil 1994). The vehicular emissions are caused by poorly maintained old trucks, buses and other motor vehicles, while the industrial sources include brick kilns, fertiliser factories, spinning mills, tanneries, garments, bread and biscuit factories, chemical and pharmaceutical industries, metal workshops, etc. (Rana 2011).

2.5.2 Surface water contamination, sewage management and ground water declination

The quality of surface water has been worsening in the rivers, lakes and canals of Dhaka due to increasing anthropogenic activities (Dewan et al. 2012). The primary sources of water contamination are industrial effluents, sewage and domestic waste that are directly discharged into the rivers (Hossain & Rahman 2012; BBS 2010; Rabbani 2009; Rahman & Hossain 2008; Sohel et al. 2003; Karn & Harada 2001). About 70% of Dhaka city dwellers do not have access to the public sewer system. Where there is no public sewer system, excrement waste from buildings is managed by septic tanks. In most cases, the effluent from septic tanks and wastewater generated from buildings are disposed of into nearby drains, which ultimately fall into the surrounding rivers or other water bodies (Haq 2008).

The most reliable natural water resource that supplies drinking water to Dhaka is under threat due to excessive exploitation and low rate of recharge (Rabbani 2009). The ground water level was 51 metres below mean sea level in 2010 against 46 metres in 2004 (Ahmad 2011). Rapid urbanisation, mainly the construction of roads, commercial establishments and housing has created massive impervious areas in Dhaka that do not allow rainwater to get absorbed by the soil. Moreover, open space and small water bodies have been considerably reduced in Dhaka (Rabbani 2009).

2.5.3 Poor waste management

The primary sources of municipal solid waste in Dhaka are residential, industrial and commercial (Hai & Ali 2005); however, household solid waste collection rose by 300% from 1985 to 2004 (JICA 2005). The waste disposal method typically practiced in Dhaka is open dumping in the low-lying areas, both inside and on the peripheries of the city (Corner & Dewan 2014), causing severe land and water pollution (UNEP 2006).

2.5.4 Decrease in water bodies, cultivated land, vegetation, wetlands and loss of biodiversity

A study by Dewan and Yamaguchi (2009a) of land use classification in the Dhaka Metropolitan area of Bangladesh demonstrated that urban developed areas increased considerably due to large rural-urban migration from 11% (in 1960) to 334% (in 2005). This has consequently caused a considerable decline in the water bodies, vegetation, cultivated areas and wetlands. The encroachment on suburban and agricultural land for the outward expansion of the city is a common practice, and this has led to a significant loss of natural resources and threats to biodiversity (Dewan & Yamaguchi 2009b). Encroachment onto ecologically sensitive areas through unplanned housing made by individual landowners, as well as private developers, along with the discharge of wastewater and solid waste into water bodies, are accountable for the degradation of the landscape and loss of biodiversity (Nahrin 2012; Byomkesh et al. 2012). The transformation of water bodies, vegetation and low-lying areas into urban land has instigated extensive and diverse environmental degradation and susceptibility to flooding (Dewan and Yamaguchi 2009b). A further study by Byomkesh et al. (2012) showed that the green spaces of Dhaka have declined over a period of time, and are becoming highly fragmented because of the increasing pace of human activity that is not only causing devastation of the landscape, ecological processes and services, but is also destroying biodiversity in urban areas.

2.5.5 Sound pollution

The extent of sound pollution in Dhaka is closely linked with urbanisation and motorisation (Alam et al. 2001). Studies of the World Health Organisation (WHO) on noise level at different locations in Dhaka found them to be beyond permissible limits in 2002 (WHO 2002). According to Alam et al. (2001) and WHO (2002), the level of sound pollution in Dhaka city exceeds the acceptable limits set by the Department of Environment. Alam et al. (2001) assert that noise level is much higher than the acceptable limit in residential areas and vulnerable institutions like schools and hospitals. Chowdhury et al. (2010) measured the noise levels at the roadside as well as at a distance of about 50 metres away from the roadside. Their findings show that the average noise level on the roadside and 50 metres away from the roadside were about 82 dBA and 73 dBA respectively, which surpasses the acceptable limit for mixed and commercial areas set by the Department of Environment.

2.6 Natural and human induced hazards

The major natural and human induced hazards in Dhaka include earthquakes (Corner & Dewan 2014; Paul & Bhuiyan 2010; Ansary 2004), flooding and water logging (Dewan 2013; Rana 2011), storms (Corner & Dewan 2014) and fire hazards (Islam & Adri 2008). The sections below provide a brief overview of each of the hazards mentioned.

2.6.1 Earthquakes

Dhaka megacity is vulnerable to major earthquakes (Corner & Dewan 2014; Paul & Bhuiyan 2010; Ansary 2004), as according to the Bangladesh National Building Code (BNBC 1993), the megacity is situated in an area of seismic zoning coefficient 0.15 g, which is ranked the second highest in terms of vulnerability (Corner & Dewan 2014). The possibility of severe damage can be expected during an earthquake (Corner &

Dewan 2014) on account of poor quality building materials and unsuitable construction methods (Ansary 2003) together with risks related to soil liquefaction, as the buildings are mainly constructed on sites built by earth-filling on alluvial deposits (Kamal & Midorikawa 2004). Since many buildings use poor quality construction materials and violate building codes, any quake with a 7.0 magnitude would cause critical human disaster (Paul & Bhuiyan 2010). A study by Ansary (2004) suggests that such an earthquake of such magnitude, primarily owing to structural failure, could threaten the lives of between 45,000 and 86,000 people, depending on the time of occurrence.

2.6.2 Fire hazards

Dhaka City has recently experienced many fire accidents and in most cases lack of proper precautionary measures, along with institutional inefficiency, insufficient equipment and lack of public awareness is exacerbating this problem (Islam & Adri 2008). At present, the authority of Dhaka city does not have a contingency plan and any sufficient preparation to avoid a large-scale fire catastrophe (Islam & Adri 2008). Bangladesh Fire Service and Civil Defense Authority (BFSCDA), the legitimate authority responsible for managing fire hazards in Bangladesh, is characterised by substandard equipment, poor technology and inadequate work force (Islam & Adri 2008). Presently, there are about 13 fire stations with an average of 35 employees, together with two vehicles (water tender and a pump) for each station in Dhaka City (BFSCDA 2007). Moreover, the equipment and communication systems that receive information and control vehicles from the control room are not modern (Islam & Adri 2008). The BFSCDA has only two modern ladders that could be used in dousing fire by throwing water up to 14-storeys of a high rise building (Azad 2009).

The narrow road systems in the city which in many cases obstruct the entrance, movement and manoeuvre of fire service vehicles at the time of emergency, and the low mobility on the road system also increase the response time of the authority and ultimately cause serious fire destruction in a minority of cases (Islam & Adri 2008). The increasing population, together with inadequate enforcement of existing building construction rules has led to in increased fire risk in Dhaka City (Islam & Adri 2008). Out of the 24 persons in the fire section of BFSCDA authorised to issue licenses for buildings (all over the country), only 4 of them are responsible for Dhaka city (Islam & Adri 2008). The current manpower of RAJUK is also not adequate to monitor and implement the building code appropriately (Islam & Adri 2008). Lack of public awareness regarding fire management makes the overall situation complex for Dhaka city (Islam & Adri 2008).

2.6.3 Flooding and water logging

Water logging is a common feature of Dhaka city owing to the absence of appropriate sewerage management, mainly during the rainy season (Rana 2011; Rabbani 2009). In addition to natural causes, unplanned infrastructure development, insufficient and inefficient drainage (Dewan 2013; Rana 2011; Alam & Rabbani 2007) and the encroachment of environmentally sensitive areas (Alam 2014; Seraj & Islam 2013) has led to flooding and water logging in Dhaka. Wetlands and water bodies which were used to mitigate recurrent monsoon flooding are being intruded on without considering the risk of potential flood disaster (Dewan et al. 2012). The susceptibility of Dhaka to flood damage is expected to increase because of continuous unplanned urban expansion (Faisal et al. 1999) and the effect of climate change (Alam & Rabbani 2007), and this will sequentially increase the misery of the residents of Dhaka and cause widespread destruction to property in the region.

2.6.4 Storms

Fierce local storms such as tornadoes and “nor’ westers” are examples of other environmental hazards in the Dhaka (Corner & Dewan 2014). As urbanisation converts natural land cover with metal and concrete infrastructure, increasing temperatures because of the heat island effect during summer are accountable for the fierce local storms in Dhaka (Rana 2011).

From the above explorations and research, it can be summarised that the most critical environmental problems in Dhaka are air pollution, surface water contamination and ground water declination, lack of waste management, decrease in water bodies and cultivated land, vegetation, wetlands, loss of biodiversity and sound pollution. In addition to environmental problems, some natural and human induced hazards include earthquakes, fire hazards, flooding and water logging and storms.

2.7 Governance for housing/ development control

Having identified existing problems in the urban settings of Dhaka, this section now examines various regulations that have impacts on housing in Dhaka.

2.7.1 Housing regulations/ development control related Rules and Acts

There are a number of rules and regulations concerning housing in Dhaka. Despite the presence of these regulations, majority of them are ineffective in controlling building development due to the loopholes that allow malpractice (Zaman & Lau 2000). These rules and regulations are discussed below:

2.7.1.1 National Housing Policy 1993

In response to the United Nation's (UN) declaration in 1988 for the formulation of Housing Policy by Nations, and the 1992 Rio de Janeiro Declaration on Environment and Development (also by the UN), the Government of Bangladesh formulated the first ever Housing Policy for the country in 1993 (Islam 2014). The Revised National Housing Policy of 1999 outlines the future role of the government as that of a "facilitator" or "enabler", rather than as a "provider", in order to increase access to land, infrastructure, services and credit, and to assure the availability of building materials at a sensible price and encourage housing finance institutions (Islam 2014; Seraj 2012). A draft of the National Housing Policy was also developed in 2008 by the Ministry of Housing and Public Works (Islam 2014). The aim of the Housing Policy 2008 was to provide appropriate housing to all citizens and to develop houses, settlements and workplaces on a sustainable and equal basis, with the intention of providing all citizens access to health facilities, safe residential and other utility services at a minimum cost (Islam 2014).

2.7.1.2 The Town Improvement (TI) Act 1953

The objectives of the TI Act intend to improve the physical and urban conditions of Dhaka City (RAJUK 2011). The Town Improvement (TI) Act 1953 for Dhaka controls proposed building development through the preparation of master plans and improvement schemes, along with their implementation and development controls (Zaman & Laing 2013).

Using the provisions of the TI Act 1953, the Rajdhani Unnayan Kartripakkha (RAJUK) has been mandated as the legitimate authority to prepare land use plans and oversee plan implementation, control development and manage the growth of Dhaka City (Mahmud 2007b). The major aim was to ensure planned development, promote a healthy urban environment, and prevent development of conflicting land use (among other things) and above all, to ensure the sustainable development of Dhaka City (Mahmud 2007b).

2.7.1.3 Bangladesh National Building Code (BNBC) 1993

The Bangladesh National Building Code (BNBC) is the legal document that governs building construction (Seraj 2012). With a view to bringing under control and ensuring a uniform standard of building construction practice in the country, the BNBC was prepared in 1993 and was formalised as a law in 2006 (Shafi 2010). The Code is supposed to establish standards for the design, construction procedures, construction material, building use (occupancy), location and maintenance of all buildings within Bangladesh (Seraj 2012). The Code considers planning, administration and enforcement, general building controls and regulations, including requirements for different uses, fire protection and services, building density and building height. The installation and use of the necessary equipment for utilities are also regulated by this Code. In 2008, the Ministry of Housing and Public Works formed a steering committee to update the BNBC 1993, but it has not yet been achieved.

2.7.1.4 Dhaka Metropolitan Development Plan (DMDP) 1995 (1995-2015)

The DMDP is the second master plan of Dhaka city that came into being in 1997, replacing the previous master plan of 1959. The DMDP addresses Dhaka's urban planning issues and sub-urban area's development at the three geographical levels (sub-regional, urban and sub-urban), and comprises the following three plans (RAJUK 2011; Seraj 2012):

- Structure Plan (SP) (1995–2015)
  The plan provides a long-term strategy up to the year 2015 for the development of the Dhaka Metropolitan Region. The plan contains a written report and policy documents with maps of suitable scale. It classifies the size and direction of expected urban growth and outlines an extensive set of policies considered essential to accomplish overall plan objectives. The plan considers the micro environmental aspects of Dhaka, both in its current urban form, in addition to future development, to keep the city free from all types of natural and human induced hazards.
- Urban Area Plan (UAP) (1995–2005)
  The plan provides an interim midterm strategy for 10 years (1995-2005) covering the urban areas within the metro Dhaka management areas. As an interim plan, the UAP was to be superseded by the various Detailed Area Plans, which cover particular geographic sub areas of the city.
- Detailed Area Plan (DAP)
  The DAP is a local level plan which is responsible for the proposed land use zoning, infrastructure and utility services. The DAP provides further comprehensive planning proposals for specific sub areas acquiescent with the SP and the UAP.

2.7.1.5 Natural Water Body Protection and Preservation of Open Space and Playground Act 2000

This legal instrument empowers an urban authority to restrict incompatible uses in environmentally sensitive areas by preventing land filling for development of residential areas (Seraj 2012; Ahamad & Hasan 2010), and to demolish any unauthorised development on such land without any compensation (Seraj 2012).

2.7.1.6 Land Development Rules for Private Housing 2004

This act is formulated only for Dhaka city and it sets specific guidelines for private residential land development and acts as a support instrument for land use control regulations of the DMDP (Seraj 2012). It comprises of the applicable rules for approval of land projects, area limit, and the maximum areas applicable for sale, land use, conserving the interest of the intended residents (GoB 2004). While the rule concentrated on social, physical and environmental standards for housing projects, no punishment facility is enforced for unauthorised development in the restricted areas (Alam & Ahmad 2011; Haque 2004). It also states specific percentage of land that must be kept for community facilities, amount of land that may be sold, school sites, road hierarchy and essentially, planning standards, for example, the allocation of land per 1000 population (Mahmud 2007b). The summary of rules that are responsible for conserving the environment this way are given below (Ahamad & Hasan 2010):

- About 30% of the project land should be preserved for setting up utility and civic amenities;
- The layout plan should be designed such that the surrounding environment, transportation, water logging, water and sewerage, drainage and other associated matters are given proper attention;
- The following community facilities should be provided in the land project: kutcha bazaar (market for fish, meat, vegetables and groceries), market, community centre, religious centre, graveyard, health centre, clinic, hospital, playground, park, open space, nursery school, primary school, high school and college; and
- Space for delivery of utility services.

2.7.1.7 Dhaka Metropolitan Building Construction Rule 2008

This statute is applicable only within the RAJUK jurisdiction and it superseded the earlier set of rules in the 1952 (Building Construction Act 52), 1984 (Building Construction Rules 1984), 1996 (Building Construction Rules 1996), 2006 (Dhaka Metropolitan Building Construction Rules of 2006) and 2007 (Dhaka Metropolitan Building Construction Rules of 2007) (Seraj 2012). The Building Construction Rules 1996, promulgated for the whole country, was at the same time too simplified and ambiguous to be imposed for a megacity like Dhaka (Seraj 2012; RAJUK 2011; Shafi 2010; Mahmud 2007a). The Dhaka Metropolitan Building Construction Rules 2008 provided more authority to RAJUK in the following ways (Shafi 2010; Mahmud 2007b):

- By spelling out the responsibilities of professionals like urban planners, architects, structural engineers, mechanical engineers, electrical engineers, geo-technical engineers, site supervisors and plumbing engineers;
- By specifying the responsibility of who was to monitor development of the city; and
- By spreading out the responsibilities to various actors.

The Building Construction Rules 2008 addresses the issues of Floor Area Ratio (FAR), ground coverage, setbacks, road widths, access and parking facilities according to site area for development; minimum room dimensions and community spaces according to building usage pattern; protective measures for constructing in environmentally vulnerable sites, as well as requirements for light and ventilations, water sanitation and drainage facilities, waste disposal, fire safety measures and universal access for acceptable living conditions (Zaman & Laing 2013; RAJUK 2008). One of the most important improvements is the introduction of FAR which manages the growth of the city by providing rules of the building coverage area and allowable floor space in relation to building height, road width and plot size (Shafi 2010).

FAR is the ratio of the total floor area of a building to the area of the plot where it is located. As a formula, FAR can be expressed as follows:

$$Floor\ Area\ Ratio\ (FAR) = \frac{Sum\ of\ areas\ of\ all\ floors\ of\ the\ building}{Area\ of\ the\ plot} \text{......} \textbf{[2-1]}$$

(Source: Seraj 2012)

FAR is directly related to the ground coverage of a building, while the ground coverage can be defined by the following expression:

$$Ground\ Coverage = \frac{Land\ area\ covered\ by\ building\ x100}{Gross\ area\ of\ land} \text{......} \textbf{[2-2]}$$

(Source: Seraj 2012)

FAR provides a trade-off between the ground coverage and the building height (number of floors). If the floor area (or ground coverage) of the building is higher, the height of the building will be lower. This can be understood from the following expression by rearranging the first expression:

$$No\ of\ floors = \frac{Area\ of\ the\ plot\ x\ FAR}{Ground\ coverage} \text{......} \textbf{[2-3]}$$

(Source: Seraj 2012)

To ensure access to natural ventilation and daylight in the building, ground coverage and the floor area ratio (FAR) have been fixed on the basis of the plot area as outlined in the following table:

Table 2-2: Maximum ground coverage and FAR based on plot size

Plot size (in Katha[4])	**FAR**	**Maximum ground coverage (%)**
2 and less	3.15	67.5
More than 2 to 3	3.35	65
More than 3 to 5	3.5	62.5
More than 5 to 7	3.75	60
More than 7 to 9	4.0	60
More than 9 to 10	4.25	57.5
More than 10 to 12	4.5	57.5
More than 12 to 14	4.75	55.5
More than 14 to 16	5.0	52.5
More than 16 to 18	5.25	52.5
More than 18 to 20	5.25	50
More than 20	5.5	50

(Source: RAJUK 2008)

Rules regarding setback distance are discussed below (RAJUK 2008):

[4] 1 Katha equals 67 square metres

Setback distance:

- The mandatory setback from the back or sides of the plot for buildings up to 10 floors are shown in Table 2-3 below:

Table 2-3: Setback distance from the back and side of the plots

Land area (square metres)	Front setback (metre)	Back setback (metre)	Side setback (metre)
Less than 134	1.5	1	0.8
135-201	1.5	1	1
202-268	1.5	1	1
269-1340	1.5	2	1.25
>1340	1.5	2	1.5

(Source: RAJUK 2008)

- For any land area, if the height of the building to be constructed is more than 10 floors or 33 metres, side and back setback is minimum 3 metres and front setback is 1.5 metres.
- Two buildings in one site must be situated at least 4 metres away from each other if in line, and 2.5 metres away if they are side by side.

Room dimensions

- Every dwelling unit in a residential building shall have at least one room, which shall not be less than 9.5 square metres with a minimum width of 2.5 metres. Other habitable rooms in the dwelling unit shall have a minimum area of 5 square metres each, with a minimum width of 2 metres
- The minimum floor area of kitchen shall be 4 square metres with a minimum width of 1.5 metres.
- The minimum floor area of a bathroom where water closet and bathing facilities are combined shall be 2.8 square metres with a minimum width of 1 metre. For bathrooms without water closet, the minimum area shall be 1.5 square metres with a minimum width of 1 metre. The minimum area of a toilet with water closet only shall be 1.2 square metres with a minimum width of 1 metre. Three fixture bathrooms containing bathing, hand washing and

water closet facilities shall have a minimum area of 3 square metres with a minimum width of 1.25 metres.

Though the new set of recommended values for FAR, ground coverage, setback rules and room dimensions were formulated with the aim of providing more liveable and open spaces for design flexibility, provision of natural lighting and natural ventilation within the built spaces and improved visual privacy, studies of the high-rise residential buildings after the onset of these rules in 2008 have not yet been undertaken to investigate whether the rules achieve the desired aims.

2.7.1.8 Real Estate Development and Management Act 2010

The Real Estate Development and Management Act 2010 is a new statute to streamline real estate development and bring it under control, and this statute is applicable to all development control authorities (Seraj 2012). The act is focused on the developers' irregularities in handling sold plots, registration, transfer and land development. However, the act is not concerned with the ecologically critical areas, has no provision for punishing the violators, and the law does not include any price control mechanism (Alam & Ahmad 2011; Haque 2004).

2.7.2 Building approval process

RAJUK is the legitimate authority for issuing approval of any building construction and it controls all the development activities of Dhaka City under the provisions of various acts and rules within the area under its jurisdiction. In order to have approval for the construction of any building, the process of obtaining approval involves the following two stages (Mahmud 2007b):

- Land use clearance

Generally, planned residential areas of RAJUK that already have the approval of RAJUK do not need to have the "land use clearance" from RAJUK. For other areas, the "land use clearance" must be obtained prior to submitting plans for construction. Land use clearance is the stage in which the proposed use of the land is crosschecked to confirm with the prepared plan by RAJUK. Land use clearances are of two types. In the first type, direct land use permit can be given if the proposed criteria of land use in a certain area match the criteria and standards set by the master plan for that area. In the second type, if there is/are any deviation/s to the master plan, the application has to be assessed through the Town Improvement TI Act 75(I)/ (II).

- Building permits

Building approval is the stage where the applicant submits an application, fulfilling specific requirements such as detailed plans, sections and elevations of the proposed building as per the Building Construction Rules. In the case of applying for building permissions for large and specialized projects such as residential building/residential cum commercial building more than 6 storeys high, RAJUK demands prior clearance certificates from the following organisations: Department of Environment (DoE), Dhaka Electric Supply Authority (DESA), Dhaka Water and Sewerage authority (DWASA), Titas Gas, Dhaka Transport Coordination Board (DTCB), Dhaka City corporation (DCC), Civil Aviation Authority Bangladesh, Bangladesh Fire Service and Civil Defence Authority (BFSCDA) and RAJUK itself (Mahmud 2007b; Seraj 2005).

2.7.3 Violation of development control rules and acts/land use plan and building regulations

Mahmud (2007c) claims that even though the official time to acquire a land use clearance is about 3 weeks, in reality, the process is so lengthy and complex that people seldom take the standard procedure of planning permission; rather, they prefer to deal with illegal agents by giving them "extra money" (Mahmud 2007c). He also found that laxity in duties, intention to waive some specific cases, poor inspection and reporting, and political influence has made the Authorised Section of RAJUK a frightening part of the organisation. He also adds that in some cases, clients or developers somehow manage the authority for land use clearances for particular areas where development is restricted for specific purposes.

In some cases, the progress of a plan or building construction approval is delayed due to some indefinite situations, which leads people to seek alternative solutions (Mahmud 2007c). Misuse of power as claimed by the clients, generates unnecessary harassment and delay (Mahmud 2007c). The provisions of the Rules clearly define that plans should be forwarded for clearance or approval within 45 days, and any objection made in the plan must be notified within 30 days after submission for approval (Mahmud 2007c). In fact, this process sometimes takes more than the specified time in the Rules, and in many cases, it actually takes years to get the necessary approval. As a result, to evade such hassle and unnecessary delay, people tend to look to other means (bribe, deploying illegal agents) for obtaining planning permits that bypass planning laws (Mahmud 2007c).

According to Mahmud (2007c), in addition to the above-mentioned violations, deviation or the violation of plans can occur at the following three different levels:

1. Micro level:

On the micro level, plot owners deviate from the building plan by constructing the building in such a way that it violates from the plans that were permitted by RAJUK. The most serious types of plan violations are:

- Not maintaining the required distance of the building from the adjacent road;
- Not maintaining the building height as per the plan;
- Not maintaining the required setback rules of building; and
- Altering the land use of the building.

(Mahmud 2007c)

2. Intermediate stage: deviation in area plan

Land use change is a violation of a local plan or the plan of the city, and the most common way this occurs is changing land use, with or without the permission of the authority (Mahmud 2007c). Without the amendment of the plan of the city, changing land use is a crime. Mostly, corruption and socio-political pressure is responsible for this plan deviation. Some different forms of deviation in area plan include:

- Converting the land use characteristics of whole/part of the plot;
- Increasing the height of buildings from the permitted height limit;
- Subdividing the plots; and
- Changing the amount of land use of the area.

(Mahmud 2007c)

3. Macro level: deviation in the proposals of structure plan

The DMDP structure plan for Dhaka city was completed in 1995. Within the last 10 years, the proposals of this structure plan were violated by the private companies, individuals and even by the RAJUK authority itself through filling in the low land and wetland area that surrounded Dhaka city, and which served the city as a flood retention area and ground water recharge zone (Mahmud 2007c).

2.8 Infrastructure and services

2.8.1 Land and housing

Dhaka is noted for a severe shortage in land and housing facilities (Hossain 2006). Dhaka would need about 4.45 million housing units over a 17-year period from 2008 to 2025 in order to fill projected demand. Of this, 1.81, 2.40 and 0.24 million housing units would be needed for the low-income groups, middle-income groups and high-income groups in Dhaka respectively (Islam et al. 2009). Despite the high increase in the number of real estate companies, the housing condition has not improved. Instead, it has remained aggravated with high prices for land and apartments ensuing, partially, from scarcity in the supply of land (Rahman 2008).

Ownership of urban land is highly inequitable, with only 30% of the population (upper and upper-middle-income households) controlling ownership or access to 80% of residential land, while the other 70% (middle and low-income groups) has access to the remaining 20% (Islam 1998; Stubbs & Clarke 1996). Nearly 30% of the middle and low-income groups fall below the hard-core poverty line[5], live in slums and squatter settlements, and are often being repeatedly pushed to ever more distant peripheral sites (Shakur & Madden 1991). Willcox (1979) demonstrates that owing to physiographic factors such as low-lying agricultural lands and natural barriers such as rivers, canals and depressions, the expansion of Dhaka city has been confined. Thus, because of the scarcity of land for development in the city, the price of land is increasing at a very rapid rate. This clarifies why the "common people" are not capable of purchasing land and building homes in Dhaka City (Hossain 2006).

Within DCC, land for housing at market price is affordable to no more than 5% of the city's households (Islam 1998). Residential land values in prime locations of Dhaka range between US$350 and $1430 per square metre, which is high even when compared to other cities in developed countries (Kamruzzaman & Ogura 2007a). Depending on the location and their size, the average cost of apartments in Dhaka varies from US$20,000 to $120,000, a cost which is only affordable to high-middle income and high-income people (Rahman 2008).

The existing housing supply situation has been characterised by "a critical imbalance" between housing cost to household income ratio that has been known to affect home ownership as well as rental housing (Kamruzzaman & Ogura 2007a). According to Kamruzzaman and Ogura (2007a), a survey conducted by the Consumers Association of Bangladesh (CAB) in 2007 revealed that housing rent in Dhaka city had risen by 250% in the last 17 years, despite the presence of rent control laws and courts.

The higher and middle-income groups are accommodated in either low-rise, single-family houses or, progressively, in multi-family apartment buildings (Hoek-Smit 1998). In view of the new types of housing being produced, formal sector private developers usually provide housing only to the upper and middle-income groups.

[5] The poor who consume 1805 kilo Calorie per day per person (BBS 2000)

The lower income households (about 70% of the urban households) are accommodated in the following house types (Rahman, K.K 2008): low-income housing units in informal settlements areas that consist of both private rental and private ownership housing, conventional tenement slums (rental and owner occupied), squatter resettlement camps (government-provided), employee housing (comprising mostly of small apartments in high-rise complexes provided by the government), makeshift houses on illegally occupied public or private land and pavement dwelling.

2.8.1.1 Problems encountered in meeting housing demand

Siddiqui et al. (2000) reveal that the housing problem has been made particularly severe by the alarming rise in the value of land, the uncontrolled price escalation of construction materials, complicated land acquisition procedures (for government housing schemes), and disorganised and inadequate housing finance. In addition to these factors, high apartment price, high house rent, property transfer and registration fee are also other obstacles in providing housing (Seraj & Alam 2009). According to a study by Chowdhury (2013), there are more problems encountered in meeting housing demand in addition to the aforementioned, being: rapid urban growth, lack of urban land management, ineffective housing policy, faulty land taxation system, lack of adequate residential infrastructure, gap between supply and demand of housing, inadequate regulatory structure, inadequate housing finance and the dominance of private developers in the housing market.

2.8.1.2 Housing delivery system and key public actors in housing provision

The private sector, composed of a predominant informal sector (55%) and a formal sector (45%), provides 90% of housing in the city of Dhaka, while the government provides 10% of housing which is for government employees (Chowdhury 2013; Siddiqui et al. 2000). The borderline between formal and informal remains unclear, since a settlement with the same characteristics in land, urban planning and housing can be considered either formal or informal depending on the contexts and interpretation of relevant public agencies (Chowdhury 2013). The formal private sector generally provides housing for the high and higher-middle-income population in Dhaka, whereas housing units in the informal settlements are found in slums and squatter settlements and are mainly for lower income groups (Chowdhury 2013). Even though the formal private sector accounts for only 27% of the entire population, it consumes 80% of the residential land, thus being the largest cause of environmental problems emanating from the housing sector in Dhaka. Due to this reason, this research focuses on housing provided by real estate developers in the formal private sector as shown in the shaded region in Figure 2-2.

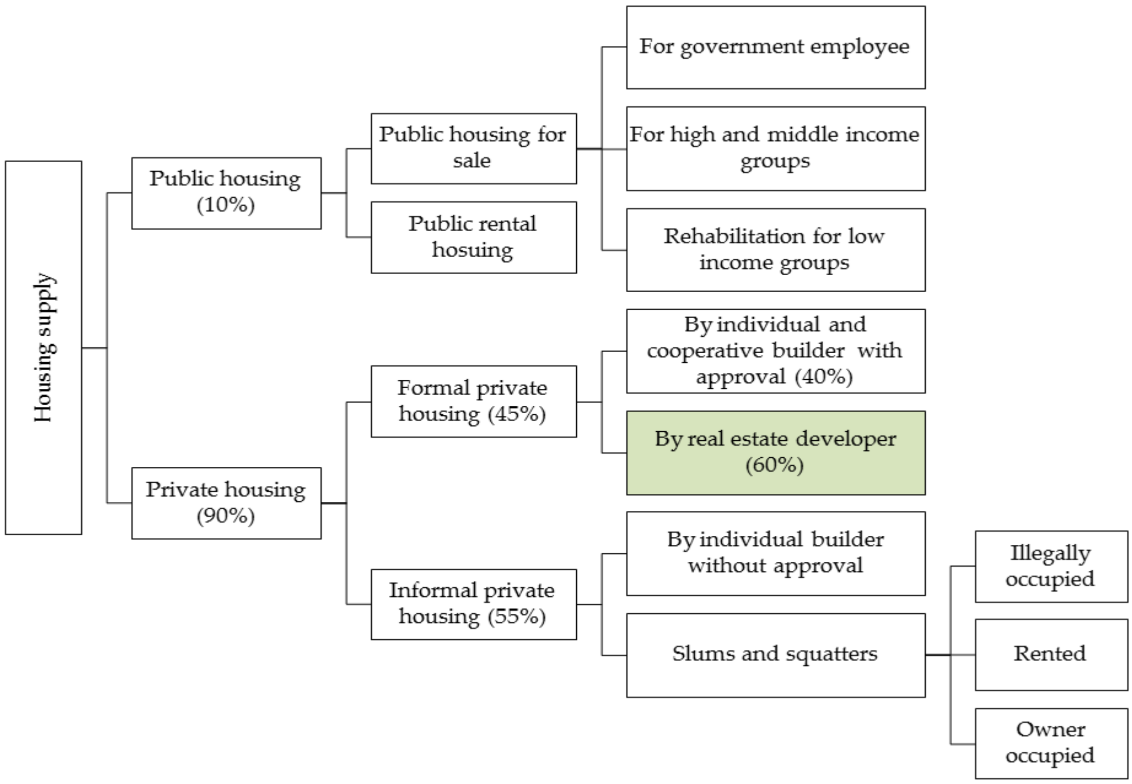


Figure 2-2: Housing delivery system

The key public actors responsible for housing and services in the formal private sector are briefly described below:

- Rajdhani Unnayan Kartipakkha (RAJUK)
  The prime role of RAJUK is to develop, improve, expand and manage the city and peripheral areas through a procedure of suitable development planning and development control (RAJUK 2015). RAJUK and the Authorised Sections are responsible for issuing land use clearances and construction approvals

(RAJUK 2015). Other main undertakings of RAJUK include construction of roads, box-culverts/culverts and bridges, and also the development, excavation and filling of land (RAJUK 2015).

- Dhaka City Corporation (DCC)
  Dhaka City Corporation (DCC), both North and South, is responsible for the construction and maintenance of infrastructure and services within its jurisdiction (Begum 2015; Nahiduzzaman 2012). It is also responsible for the collection of holding tax, which includes property and conservancy tax (sanitation, solid waste management, and street lighting) (Begum 2015; Nahiduzzaman 2012). As per the Local Government (City Corporation) Act-2009, both North and South can perform activities relating to town planning.
- Dhaka Water and Sewerage Authority (DWASA), Dhaka Electricity Supply Company Ltd. (DESCO) and Titas Gas
  The Dhaka Water and Sewerage Authority (DWASA) is formally responsible for water supply, drainage, sewerage, and sanitation services (Nahiduzzaman 2012). DESCO (formerly known as DESA) is the provider of electricity (Nahiduzzaman 2012), while Titas Gas is responsible for supplying gas in residential, commercial and industrial buildings.
- The House Building Finance Corporation (HBFC)
  The HBFC is the only public sector agency for meeting the needs of mortgage finance (Begum 2015). One of the eligibility criteria for accessing such loans is to hold a land title in Dhaka, which therefore limits these loans to higher-middle and high-income people (Karnad 2004). Currently, the annual interest rate of the loan is 12% (BHBFC 2015).
- National Housing Authority (NHA)
  The NHA is the main public sector agency responsible for solving the massive housing problem of the country, particularly for the poor, and the low and the middle-income groups (NHA 2015). The National Housing Authority (NHA) is also responsible for the development and distribution of serviced residential

plots and the construction of medium-sized and multi-storied apartments (Chowdhury 2013).

- Housing and Building Research Institute (HBRI)
  The HBRI is responsible for research and development in building construction and building materials, and for providing consultation and advisory services in the field of housing and building research (HBRI 2015).

2.8.1.2.1 Private real estate housing practice

Emergence of the real estate development

Private real estate development in Bangladesh started in the late 1970s and early 1980s in response to the public sector's inability to meet housing demand in the country and in Dhaka, where the demand versus supply discrepancy had been the highest (Seraj 2011). Once the real estate development business appeared to be a win-win situation for all three actors involved (landowner, developer and apartment buyer), more and more real estate developers ventured into this market (Seraj 2011). In the early 1980s, there were five developers, however, by 2012 the number stood at 1081 (Seraj 2012), demonstrating that since the late 1980s on average each year 34 new real estate companies have come into operation, a growth rate that highlights the lucrative nature of housing as an investment sector.

According to Mohiuddin (2014), the key reasons behind the development of real estate in Dhaka city are as follows:

- Rapid rise in the population of the city;
- Scarcity of unoccupied lands in important parts of the city;
- Extremely high prices of land;
- Problems related with the purchase of land;
- Profit motives of the land owners;
- Increase of remittance inflows that finance many purchases;
- Restructuring of households to single family units; and
- Standard of security and other services in apartments.

Throughout the last 20 years, 700,000 to 800,000 apartment units in Dhaka were provided by the real estate developers (Kamruzzaman & Ogura 2007b). According to them, the developers are important actors in the urban land and housing markets, especially in the market for apartment buildings.

Trend of apartment development

The trend of apartment development in Dhaka emerged as land price and construction cost increased significantly (Hussain 2010; Kamruzzaman & Ogura 2007b). Apartment development started to become popular as it appeared to be profitable for the two partners, the landowner and the developer, and convenient for the apartment buyer (Seraj 2011). For the developers, real estate development has been profitable because the demand for housing has always been much higher than its supply. The landowners find it both profitable and convenient, because compared to simply selling the land, a partnership with a developer yields a higher price (Seraj 2011). The convenience associated with this partnership for the landowner is that the trouble related to construction and the cumbersome procedures of obtaining building permits can be avoided (Seraj 2011). The apartment buyer prefers to dwell in apartments for the following reasons (Seraj 2011; Hussain 2010):

- Families have evolved as a nuclear type from the previously predominant joint type (extended family), with an average household size of 4.2 persons (STP 2005), and such families find it convenient to dwell in apartments with two to three rooms;
- The apartments are within the affordability range of middle and higher-middle income people, even though the land value is not affordable to most in the middle and higher-middle income group;
- The services and security in the apartments are mostly better than that of other housing types; and
- The apartments usually accommodate community centre for ceremonies and a communal prayer room.

These apartments produced by formal private real estate developers generally cater only for the upper and middle-income groups (World Bank 2007) as is evident from a study conducted in 2010 by Seraj (2012), which found that the monthly average household income of the apartment dwellers is Tk.60,660 (US$879). The "lower cost" apartments sell for approximately 1 million Takas[6] (US$17, 000) and with a 50% down payment and under current credit conditions, the apartments can be repaid with monthly payments of Tk.5,000 (US$72). Thus, the required minimum income of the household would be of Tk.15,000; in other words, only those in the top 30% of the distribution of income in Dhaka could afford to purchase such housing (World Bank 2007).

Regardless that these types of apartments are expensive (for most), the findings of a survey in 2010 showed that nearly 6000 projects (apartment complexes) comprising more than 100,000 apartments were undertaken by real estate developers, with only 40% of these apartments and projects still being under-construction at the time of the survey in 2010 (Seraj 2012). The trend of apartment development, thus suggests that the private real estate sector in Dhaka could be expected to grow at a greater pace in the following years (Seraj 2012; Hussain 2010).

Current practice of apartment development

A study conducted by HBRI and CUS (2010) shows that the number of high-rise buildings in Dhaka city is increasing day by day. Out of the 105 buildings surveyed, 28.57% of the high-rise buildings were constructed between 2001 and 2005, whereas only 1.90% of the buildings were constructed from 1981 to 1985. The same study, in this case on 2150 high-rise buildings (residential, commercial and mixed-use) in Dhaka Metropolitan Area and Dhaka City Corporation, shows the floor-wise distribution of the buildings to be as follows: 65.3% of the buildings were between 7 to 9 floors, 23.44% of the buildings between 10-14 floors, 11.16% of the buildings between 15 to 25 floors and less than 1% of the buildings were above 25 floors. The

[6] Taka is the currency for Bangladesh. US$1 Dollar = 69 Taka

majority, about 33% of buildings, were 7 floors. Another survey conducted in 2010 on 5913 residential apartment complexes (of which 41.7% were under construction) in the Dhaka City Corporation area shows that the average number of floors in the buildings was 8 storeys (Seraj 2012). About 96% of these buildings were residential, while 1% was commercial and 3% provided mixed use. Apartment size, number of rooms and design of the apartments mainly depend on the socio-economic status and household size of the dwellers (Kamruzzaman & Ogura 2007b). About 50% of the apartments were found to be between 93 to 149 square metres. A very small percentage, about 2% of the apartments, was less than 65 square metres, indicating that the real estate sector has not quite been able to address the needs of low-income groups. It must, however, be noted that even though the apartment size is an indicator of the income group, this can barely represent the reality in the case of Dhaka as apartment price largely depends on the land price and location.

Public housing projects in Dhaka by RAJUK, as well as private development projects, mainly target higher income residents because of the huge demand from those targets (Alam & Ahmad 2013). RAJUK develops and supplies service plots in planned residential areas for the upper and middle-class people of society. The prices of public sector land plot allotments have been comparatively lower than that of private housing projects (Alam 2011). Apartment prices were found to increase at an annual average rate of 14.4% for three main reasons: increase in land price, unprecedented increase in the price of construction materials and higher degree of competition amongst the real estate developers due to the increase in their number. Both apartment price and apartment rent varied with the locations. The average rent per square metres in the city was Tk.172 per month (US$2.5). It is to be noted that the average apartment prices in terms of per square metres prices in different areas in the decade from 2000-2010 have witnessed the biggest jump, increasing almost at an average of 280% (Das 2014).

Problems and prospects of apartment development

Criticisms of private sector apartment developments have been identified by various authors. While there are criticisms regarding certain aspects that have been reported, some issues have not yet been reported. These criticisms categorised firstly according to the social and secondly according to the environmental aspects, are presented below:

1. Social:

Munni (2010) conducted a questionnaire survey in four high-rise residential buildings in Dhaka to explore the current spatial arrangement and social living quality of the dwellers there. The social parameters investigated include twelve questions on networking, trust, cooperation and social cohesion. According to Munni (2010), traditional Bengali culture and values (such as social interaction, hierarchy of space) are not reflected in the high-rise residential buildings of Dhaka. It is must be noted here that the sample size of this study and data analysis are not presented in the study.

The Bengali value structure can be represented through the organisational model of the Bengali house having the two distinct zones: formal and informal (Islam 2003). The formal zone in the traditional Bengali society is the outermost part of the house, whereas the informal zone is the innermost part of the house, where all of the internal functions such as sleeping, cooking, washing are carried out. According to a study of two high-rise residential buildings in Dhaka by Sheikh (2006), this traditional organisation of space is absent in the high-rise residential buildings of Dhaka. In addition, Seraj and Alam (2009) identified that buildings in general, not necessarily high-rise residential buildings, do not have any relationship with the surrounding built environment. However, Hossain (2007), at a broader scale, recommended conservation at urban level to be carried out as a continuous process by maintaining the traditional pattern of development, he too, did not specifically mention high-rise buildings.

Problems related to the spatial design of high-rise residential buildings in Dhaka were identified as:

- Lack of open spaces (Mridha 2015; Munni 2010; Hussain 2010; Razzaque & Nahid 2007);
- Inadequate distance between buildings (Khan 2012; Hussain 2010);
- Small sized rooms (Hussain 2010);
- Lack of visual privacy (Khan 2012; Hussain 2010; Iqbal 2005);
- Lack of playing areas for children (Munni 2010; Hussain 2010; Shafi 2010; Razzaque & Nahid 2007); and
- Lack of community space (Mridha 2015; Munni 2010; Hussain 2010; Razzaque & Nahid 2007; Iqbal 2005).

Even though a lack of open space, inadequate distance between high-rise residential buildings and small sized rooms were reported, no study has been undertaken to specify what may or should be the desirable open space, distance between buildings and room size. Similarly, even though lack of visual privacy, playing areas for children and community space were reported, no study has been undertaken to improve these situations. Even though lack of visual privacy and inadequate distance between buildings was reported, no study has been conducted to investigate the relationship between visual privacy and distance between buildings to specify the minimum distance between buildings that may improve visual privacy.

Despite the problems of high-rise residential buildings mentioned above, one advantage of living in high-rise residential buildings as identified by Hussain (2010) is community safety and security.

MOHPW and RAJUK (2010) have identified the following neighbourhood facilities for any neighbourhood measuring 50 acres (20 hectares) with a gross density of 225 persons per acre (562 persons per hectare): supermarket, pharmacy, grocery shops, rickshaw/auto-rickshaw stand, mosque/worship place, playground, doctor’s chamber, municipal waste collection points, technician services , park, laundry, hair dresser, photocopy/mobile/land phone/fax service, beauty parlour, computer based service, tailoring, community police/barrack, cyber cafe/internet service provider, restaurant, tea bar, fast-food, vehicle repair services, recreational facilities, fruit shop, community club (including indoor games), high school, primary school, cultural facilities, sweet shop, post office/courier services, flower shop and library. To date, no study has been conducted that explores the occupants' preferences of desired neighbourhood facilities for high-rise residential buildings.

Haq (2007) has stressed the importance of both the preventive and corrective maintenance at regular intervals, explaining that due to lack of maintenance, buildings may become unsafe long before the end of their expected service life. In regards to maintenance, Mridha (2015) found that repairs in apartments of medium-rise buildings were made promptly. In support of maintenance plans, Paul and Bhuiyan (2010) have expressed that the institutionalisation of preparedness is essential to reduce the level of risk from extreme natural events for the occupants/ citizens, as their study found that an overwhelming majority of the occupants of residential buildings in Dhaka are not prepared for a major earthquake. Their study, however, does not clarify whether the investigated buildings were high-rise or low-rise buildings.

In regards to awareness and education, Paul and Bhuiyan (2010) have stated that awareness of the effects of hazards such as earthquakes through education programs initiated by the government has not been completely successful. Ahsan and Rahman (2007), on similar notes regarding education, explained that environmental and sustainable building principles are not at the centre of the architectural discourse in Bangladesh.

2. Environmental and technical

Inadequate daylight and inefficient natural ventilation (Hussain 2010) have been identified as the key problems of the built environment in high-rise residential buildings.

Fire safety has also been found to be insufficiently addressed in high-rises (Haq 2007; Iqbal 2005). Islam and Adri (2008) have recommended addressing fire safety issues from the individual building premises to the city level planning, provision of fire drills and mandatory training for the staff and occupants of buildings to be arranged by the Bangladesh Fire Service and Civil Defence Authority. The narrow road systems, a characteristic of most areas of Dhaka city, block the entrance and movement of fire service vehicles during emergencies (Islam & Adri 2008). In addition, the majority of high-rise residential buildings does not have the specified setback distance between them and adjacent buildings (Haq 2007), and most have encroached upon the streets and roadways (Paul & Bhuiyan 2010). Consequently, a sudden fire in one building can spread rapidly to neighbouring structures (Haq 2007) and when the building collapses, it will block streets, further hindering rescue operations (Paul & Bhuiyan 2010).

The violation of building codes (Nahrin 2012; Mourshed 2011; Mahmud 2007a; Seraj 2007; Iqbal 2005; Rahman & Mowla 2003; Hafiz 2000), substandard construction (Hobson 2013; Hafiz 2000) and constructional defects that lead to cracks in the floors and walls (Seraj & Alam 2009) are widely prevalent in Dhaka.

Safety rules are usually defied on construction sites (Rahman 2011). According to Shafi (2007), accidents and deaths due to the faulty construction of buildings are rising due to the lack of implementation of safety features in the building code. A study undertaken by the Bangladesh Institute of Labour Studies (BILS) revealed the death of about 487 construction workers at work in just six months (Sultana 2012). The causes of workplace accidents include the following: workers not given the appropriate safety equipment or training, working at great heights and in confined spaces, while also having to handle harmful chemicals and dangerous machinery without protection (Sultana 2012). Safety measures for the pedestrians are not assured as most building owners also do not implement any safety measures for pedestrians before starting construction work on the building (The Daily Star 2014).

Regarding solid waste management, the main challenges encountered by the municipal authorities in Dhaka are the swiftly rising population numbers and per capita volumes of waste produced, absence of source separation of organic, recyclable and hazardous materials, and lack of space available for sanitary waste transfer and treatment (Matter et al. 2015). According to Alam and Ahmad (2013), lack of waste disposal systems in both public and privately developed residential areas is among the major physical environmental problems. Ahsan and Zaman (2014) explored the socio-demographic, socio-cultural and environmental features in waste management systems in 117 high-rise apartments in Dhaka. Garbage chutes were present in only 5 out of the 117 apartments surveyed. They found that all the apartments surveyed had only one bin for collecting their waste. Waste from the individual bins of most of the flats is emptied into a bin brought in by the waste collector during their door-to-door collection service. Even though recycle bins were provided by the housing authority in some buildings, they were found to be either unused or used for other purposes.

Regarding construction and demolition waste, Waste Concern (2010) has reported that only 25% of the developers reuse the construction waste from their projects, while the remaining 75% dispose construction waste in low-lying lands.

2.8.2 Electricity, gas, water and sanitation

Almost all areas of the infrastructure in Dhaka face severe problems and these include electricity supply, gas and fuel supply, water supply and sewerage management (Hossain 2006). High-rise apartments generate enormous pressure on the following urban utility services: electricity, gas and water supply and sewerage disposal (Islam 2014; Iqbal 2005).

While the higher and middle-income groups of the city have access to gas supplies, most of the poor people do not have access to the urban gas supply (Rana 2011). Owing to the scarcity in gas supply, the government stopped providing new gas connections for the residential sector in 2010, and for commercial, power plants, fertiliser and other industrial purposes since 2009 (Rasel 2013). In Bangladesh, gas for residential use is provided under a fixed rate and this encourages unlimited usage at each household (JICA 2015), indicating that the need for gas meters to be employed in buildings.

The quantity of water supply is insufficient, especially in summer, when the dwellers of Dhaka city suffer terribly from the shortage of water supply (Rana 2011). During the period 2012-2103, Dhaka was short of 60 million litres of water per day (DWASA 2013). Adding to this pressure of water shortage, unorthodox plumbing practices in buildings also generate huge losses of water.

The quality of water supplied by the Dhaka Water & Sewerage Authority (DWASA) is poor (Rana 2011; Islam 1998) and people need to boil it to make it safe for drinking. Even though sources of drinking water vary with the locality in Dhaka, groundwater serves as the major source (Ahmed et al. 2005). In 2007, about 60% of total water connections were metered, while the 40% unmetered were paying a fixed sum per month depending on the annual valuation of the property (DWASA 2007). In December 2010, the percentage of metered connections rose to about 70% (Gunawansa & Hoque 2012). Nevertheless, water conservation is neglected in Dhaka and despite the availability of efficient fixtures, very few households have installed them (Gunawansa & Hoque 2012).

Islam et al. (2011) and Islam et al. (2010) asserted that rainwater harvesting is potentially a very useful source of safe water for drinking, cooking and washing purposes. However, they do not explore the issues regarding the management of storm-water for landscaping and minimising water use during the construction of the buildings.

2.9 Conclusion

This chapter situates the research within the contextual settings of Dhaka and highlights the state of governance for housing/development control and the infrastructure services in Dhaka, with particular emphasis on the trend of high-rise apartment living and problems and prospects associated with this.

The literature review has identified social and environmental issues that are important in the construction of high-rise residential buildings. It has also identified issues that have not been explored, but could be of importance and which are discussed below:

- Bengali culture and values are not reflected in the high-rise residential buildings. The importance of the relationship between the high-rise residential buildings and the surrounding built environment has not been studied. In addition, the importance of maintaining the heritage value at the urban level in the vicinity of high-rise residential buildings has not been mentioned.
- Community safety and security in high-rise residential buildings were reported to be an advantage of high-rise living, though not explored explicitly.
- Even though lack of open space, inadequate distance between high-rise residential buildings and small sized rooms were reported, no study has been undertaken to specify the adequate area of open space, distance between buildings and room size. Similarly, even though lack of visual privacy, playing areas for children and community space were reported, no study has been undertaken to provide solutions to improve these situations. While these issues were reported, no study has been conducted to investigate the relationship between visual privacy and distance between buildings to specify the minimum distance between buildings that may improve visual privacy.
- Though MOHPW and RAJUK (2010) have identified 30 neighbourhood facilities for any neighbourhood measuring 50 acres (20 hectares) with a gross density of 225 persons per acre (562 persons per acre), to date, no study has been conducted that explores the occupants' preferences of desired neighbourhood facilities for high-rise residential buildings.
- Even though Haq (2007) has emphasised the importance of maintenance at regular intervals, he did not study the existing scenario of maintenance issues

in high-rise buildings in Dhaka. The importance of long-term maintenance plans for high-rise residential buildings has not been discussed.

- The importance of emergency preparedness planning and the awareness and education programmes on the effects of earthquakes, in general, not necessarily for high-rise residential buildings were studied. On a similar note regarding education, it was found that environmental and sustainable building principles were not at the centre of architectural discourse; this again did not address environmental and sustainable building principles for high-rise residential buildings.
- Despite inadequate daylight and inefficient natural ventilation were identified as the problems of the built environment, no study has been undertaken to specify the natural day-lighting in rooms and recommend ways of improving natural ventilation. Further, no study was conducted to study whether floor level or distance between buildings had any role in influencing daylight and natural ventilation. Studies of internal noise measurements as part of the built environment, and ways of improving the noise level in different floors of high-rise residential buildings in Dhaka were also not discussed.
- Though there is evidence of literature focusing on construction practices in Dhaka, such as safety rules on construction sites and safety measures for pedestrians, they were not specific to high-rise residential buildings.
- While household solid waste management in high-rise residential buildings was studied, no recommendations were made to increase its efficiency. Even though the absence of source separation of organic, recyclable and hazardous materials was expressed as a general concern in a study, it did not focus on high-rise residential buildings. The management of construction and demolition waste in high-rise residential buildings was not studied extensively.
- Though the studies have noted a shortage of gas and water supply, there is no study on the use of gas and water meters for efficient gas and water usage in high-rise residential buildings.

- Though studies address that high-rise residential buildings generate enormous pressure on electricity, gas and water supply, no study has been undertaken to measure the actual energy and water consumption in these buildings.

Whilst the literature has identified a few criteria under the social issues that can be categorised into the following sub-issues: culture and heritage, spatial design, community safety and security, maintenance, awareness and education, it has not found any studies that examine the criteria and effects upon local employment.

Similarly, while the literature has identified a few criteria relating to environmental issues that can be categorised in the following sub-issues: built environment, construction practice, ecological impact, impacts on nearby water body, impacts on air, water management, energy management and waste management, it has not identified any study that looks into the criteria on site selection, impact on adjacent properties and building materials.

Though various social and environmental issues of high-rise residential buildings have been reported by many scholars as separate studies, no comprehensive study has been conducted so far to investigate if proper consideration of these issues could lead to socially and environmentally sustainable strategies for high-rise residential buildings in Dhaka. It is also not clear to what extent their importance (and their relative importance) to all the stakeholders in the building construction industry of Dhaka, including the building occupants might be. Table 2-4 summarises all the social and environmental issues studied by various scholars and presented in Chapters 1 and 2. These reported issues have been identified as among the criteria that would need to be investigated to obtain views of all the stakeholders in the building construction industry in Dhaka and in some cases, the occupants of high-rise residential buildings in Dhaka in order to develop strategies for socially and environmentally sustainable practice in high-rise residential buildings here.

Table 2-4: Summary of social and environmental issues about high-rise residential buildings that were reported

Social issues		
Sub-issues	**Reported**	**Remarks**
Culture & heritage	Consideration of local cultural value	No remarks
	Relationship of design with existing streetscape	Not specific to high-rise residential buildings
	Maintenance of heritage value at urban level	Not specific to high-rise residential buildings
Spatial design	Lack of open spaces	Does not specify the amount of space that should be left open
	Inadequate distance between buildings	Does not specify the distance between buildings
	Lack of playing areas for children	No recommendation on the ways of improving this situation
	Lack of community space	No recommendation on the ways of improving this situation
	Lack of visual privacy	No study on relationship between visual privacy and the distance between buildings
	Small sized rooms	Does not specify room size
	Neighbourhood facilities for any neighbourhood measuring 50 acres with a gross density of 225 persons per acre.	Occupants' preferences of desired neighbourhood facilities for high-rise residential buildings not studied.
Community safety & security	Community safety and security is an advantage	Aspects that provide community safety and security not discussed
Maintenance	Long term maintenance plan	Not specific to high-rise residential buildings
	Emergency preparedness planning	Not specific to high-rise residential buildings
Awareness & education	Awareness of the effects of hazards through education programs	Not specific to high-rise residential buildings
	Sustainable building principles are not at the centre of the architectural discourse in Bangladesh	Not specific to high-rise residential buildings
Local employment		Not reported
Environmental issues		
Sub-issues	**Reported**	**Remarks**
Built environment	Inefficient natural ventilation	No study on relationship between floor level or distance between buildings and natural ventilation.
	Inadequate daylight	Does not specify the daylight in rooms
		No study on relationship between floor level or distance between buildings and daylight
	Noise level	No study of noise at various levels of high-rise apartments in Dhaka

Environmental issues		
Sub-issues	**Reported**	**Remarks**
Construction practice	Violation of building codes	No remarks
	Substandard construction	No remarks
	No safety rules in construction sites	Not specific to high-rise residential buildings
	No safety measures for the pedestrians	Not specific to high-rise residential buildings
	Workers not given the appropriate safety equipment or training	Not specific to high-rise residential buildings
	Fire safety is insufficiently addressed	No remarks
	Provision of fire drills	No remarks
	Mandatory training for the staff and occupants of buildings	No remarks
	Provision of easy accessibility of fire fighting vehicles	No remarks
Ecological impact	Open space and water bodies are not conserved	No remarks
Impacts on nearby water body	Brick kilns constructed near river banks cause damage to water bodies	No remarks
Impacts on air	Air pollution during construction of bricks	No remarks
Water management	Unmetered water connections paying a fixed sum per month	No study on importance of water meters
	Water efficient fixtures in very few households	Not specific to high-rise residential buildings
Energy management	Unlimited gas usage at household level	No study on importance of gas meters
	Pressure on electricity supply	No study on actual electricity use of high-rise apartments.
Waste management	Absence of source separation of organic, recyclable and hazardous materials	Not specific to high-rise residential buildings
	Reuse of construction waste	Not specific to high-rise residential buildings
Site selection		Not reported
Impact on adjacent properties		Not reported
Building materials		Not reported

3 Literature Review

3.1 Introduction

To date, no efforts have been made to develop sustainable high-rise residential buildings in Dhaka. The first seminar on tall buildings in Dhaka was organised by Bangladesh Steel Re-rolling Mill in September 2012 (Star Business Report 2012). This was the first initiative to acknowledge the need to build taller structures in a sustainable manner. The Bangladesh National Building Code (BNBC) is being upgraded and is thought to include sections on sustainability and green design (InstituteBE 2013). The development of strategies for socially and environmentally sustainable practices in Dhaka is a means to deal with the complex multiple criteria in building development in relation to high-rise residential buildings in Dhaka.

This chapter aims to evaluate the key concepts of sustainable construction and sustainable building, and its relationship to high-rise residential buildings through a literature review. The review will form the basis for the study of sustainable high-rise residential buildings in Dhaka.

This chapter is divided into seven sections. The first section reviews the development of the concept of sustainable construction, followed by the concept of sustainable building. The third section concentrates on sustainable high-rise buildings, followed by sustainable high-rise residential buildings. The fifth section focuses on the satisfaction of high-rise living, while the sixth section explores the concerns of those living in high-rise residential buildings. The factors that affect energy use in high-rise residential buildings are investigated in the seventh section.

3.2 Sustainable Construction

The Agenda 21 on Sustainable Construction for Developing Countries (A21 SCDC) proposes the following definition to capture this broad understanding of the construction:

> *"Construction is the broad process/mechanism for the realization of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to deconstruction, and the management and operation of the built environment"*(Plessis 2002, p. 4).

Construction, which provides housing, workspace, utilities and transport infrastructure, is of great economic importance both in developed and developing countries in terms of investment, employment and contribution to GDP, also has severe environmental and social consequences (Plessis 2007; Burgan & Sansom 2006; Zhang et al. 2000). The construction industry has so far used up two-fifths of global raw stone, gravel, and sand; one-fourth of virgin wood; and it uses 40% of total energy and 16% of fresh water annually (Dixit et al. 2010; Langston & Langston 2008; Tommerup et al. 2007; Urge-Vorsatz & Novikova 2006; Ding 2004; Horvath 2004; Arena & de Rosa 2003; Lippiatt 1999) and has been a major producer of material waste (Baldwin et al. 2009). The construction industry is both directly and indirectly accountable for greenhouse gas emissions, due to the energy used for raw material extraction, transportation, construction, operation, maintenance, demolition etc. (Sorrell 2003; Rwelamila et al. 2000). Hence, there is concern about improving construction practices to reduce their harmful effects on the natural environment (Holmes and Hudson 2000; Cole 1999).

Over the years, many researchers have examined the effects of the construction industry on the environment (Cole 1998; Treloar 1996; Vanegas et al. 1996; Spence & Mulligan 1995 and Ofori & Chan 1998), stating that the construction industry causes environmental impacts, mainly the loss of soil and agricultural land, the loss of forests and wild lands, air and water pollution, and the loss of non-renewable energy source and materials. These environmental impacts are consistent with the environmental impacts in Dhaka discussed in Sections 1.2.1 and 2.5. In addition, Ofori & Chan (1998) also proposed that the effects of construction activities on the environment include:

- Antagonistic effect on the developed plots of land and their environment;
- Extensive consumption of both renewable resources and non-renewable resources;
- Generation of considerable amount of waste;
- Use of huge amounts of energy during the processing of materials, the construction process and the operational process of the constructed project; and
- Disturbance in the lives of people residing in the proximity of the project caused by traffic diversions, sound pollution and others.

There is a growing agreement that suitable strategies and actions are needed to make the built environment and construction activities more sustainable (CIB 1998). Following the Habitat II conference in 1996, the CIB (International Council for Research and Innovation in Building and Construction) W82 project was undertaken to understand the effects of sustainable development on the construction industry by the year 2010. The objective of the research was to describe the meaning of "sustainable construction" from the perspective of the participating countries (Belgium, Finland, France, Hungary, Ireland, Italy, Japan, Malaysia, Netherlands, Romania, South Africa, Spain, the United Kingdom and the United States of America), as sustainable construction has distinct approaches and different priorities in different countries (CIB 1999).

Though the expressions "green building", "ecological building" and "sustainable architecture" have been used for quite some time, the first definition of sustainable construction was put forward by Charles Kibert in 1994 (Plessis 2007) as:

> *"The creation and responsible management of a healthy built environment based on resource efficient and ecological principles"*(Kibert 1994 cited in CIB 1999, p. 41).

Other definitions include:

- "*Sustainable construction, in its own processes and products during their service life, aims at minimising the use of energy and emissions that are harmful for environment and health, and produces relevant information to customers for their decision making*" (Huovila & Richter 1997 cited in Huovila 1998, p. 7);
- "*Sustainable construction is* a *way of building which aims at reducing (negative) health and environmental impacts caused by the construction process or by buildings or by the built environment*" (Lanting 1998, p. 6);
- "*Sustainable construction is the use and/or promotion of a) environmentally friendly materials, b) energy efficiency in buildings, and c) management of construction and demolition waste*" (UNEP 2003, p. 7); and
- *"Sustainable construction is the sustainable production, use, maintenance, demolition, and reuse of buildings and constructions or their components*" (CIB 2004, p. 2).

According to Plessis (2007), these definitions focused mainly on environmental impact. In order to develop a global framework and terminology for Sustainable Building Construction, the Agenda 21 on Sustainable Construction was formulated (CIB 1999). This document emphasized the uselessness of endeavouring to attain a common short definition and pressed for locally suitable ways to respond to both global and local challenges and opportunities. At the time that the Agenda 21 on Sustainable Construction was formulated, importance was given to non-technical issues. These "soft issues" that are vital for Sustainable Construction include the economic, social, cultural and cultural heritage implications of the built environment (CIB 1999). The Agenda 21 on Sustainable Construction identifies the following challenging domains for a Sustainable Construction Sector:

- Management and organisation;
- Product and building issues;
- Resource consumption;
- The impacts of construction on sustainable urban development;
- Environmental burdens; and
- Social, cultural and economic issues

The Agenda 21 for Sustainable Construction also points to several differences between developed market economies, transition economies and developing countries (Plessis 1999). These differences relate to interpretations of terminology, technological needs, market emphasis, identified priorities, and the scale and types of challenges and barriers to be encountered. The report also acknowledges the criticism that the international dialogue on Sustainable Construction showed an absence of the developing world and its problems (Plessis 1999).

As a first step to acknowledge the problems of developing countries, Agenda 21 for Sustainable Construction in Developing Countries (A21 SCDC) was formulated in 2002 (Plessis 2002). The A21 SCDC defines sustainable construction as:

> *"a holistic process aiming to restore and maintain harmony between the natural and the built environments, and create settlements that affirm human dignity and encourage economic equity"* (Plessis 2002, p. 8).

This definition takes sustainability a step further than just decreasing negative impact, as inferred in the earlier definitions, by presenting the notion of reinstating the environment, in addition to emphasising the social and economic aspects of sustainability, clearly outlining what the goals for these aspects are (Plessis 2007).

As discussed above, sustainable construction has some essential requirements for both developing and developed countries. In Bangladesh and other developing countries of South Asia and Southeast Asia, sustainable construction is generally a new concept for the construction industry. Bangladesh, along with some Southeast Asian countries, has yet to formulate a sustainable development strategy and action plan particularly for the building sector. Bangladesh, Indonesia, Myanmar and the Philippines have developed their own Agenda 21 national sustainable development strategies, whereas Singapore has a Green Plan, Thailand a National Economic and Social Development Plan, Vietnam a National Strategy for Environmental Protection to 2010 and Malaysian Vision 2020 (Shafii & Othman 2005).

Some essential requirements for sustainable construction in developing countries have been identified by Reffat (2004) as: sustainability is a necessity, efficient management of resources, shared responsibility, quality improvement of construction processes and products, improving the capacity of the construction sector and the need for integrated research. Whatever the different priorities that exist for developing and developed countries, for development to be sustainable, it is important to understand the local context and priorities. The assessment of sustainable development in the building sector must respond to the context in which it is to be used.

The notion of sustainability in building and construction initially focused on concerns of limited resources, especially energy, and on how to reduce impacts on the natural environment with importance of technical issues such as building materials and components, construction technologies, design ideas related to energy efficiency (UNEP 2001) and environmentally orientated construction designs (Reffat 2004).

The concept of sustainable construction now goes beyond environmental sustainability to include non-technical issues (soft issues), giving recognition to economic and social sustainability concerns (Shafii et al. 2006; Reffat 2004) which emphasise possible value addition to the quality of life of individuals and communities (Reffat 2004), as well as cultural heritage of the built environment as being equally important (Shafii et al. 2006).

3.3 Sustainable Building

While the concept of sustainable construction includes related infrastructure and services such as roads and bridges, sustainable building concerns the sole process of creating buildings, hence, sustainable buildings can be considered as a subset of sustainable construction. The OECD Project defines sustainable buildings as

> *"buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global settings* (OECD 2004, p. 21)."

The project also defined sustainable buildings as building practices, which strive for integral quality (including economic, social and environmental performance) extensively. The OECD project identifies the following five objectives for sustainable buildings (OECD 2004):

1. Efficiency of resource;
2. Efficiency of energy;
3. Prevention of pollution (indoor air quality and noise abatement);
4. Coordination with environment; and
5. Integrated and systematic approaches.

Although sustainable building is a multidimensional concept, attention is solely given to environmental issues, disregarding the importance of social, economic and cultural issues (Mateus & Braganca 2011). Hence, the sustainable design, construction and use of buildings are based on the best trade-off between environmental aspects, social aspects (relating to users' comfort and other social benefits) and economic aspects.

To achieve the above, many have developed checklists of recommended design (Williamson et al. 2003). For instance, the Hannover Principles were developed by the architect William McDonough when he was commissioned by the city of Hannover, Germany, to develop guidelines of design for sustainability for the Expo

2000 World's Fair (Williamson et al. 2003). Williamson et al. (2003) however, argue that while checklists of recommended design can show a range of possibilities with a positive note, they risk giving conflicting guidelines on how to proceed with design. They also stress that even though these recommendations are intended to help people design, they do not necessarily help in this respect, and may actually mislead, because they cannot deal with the complexities and uniqueness of a particular design situation. Williamson et al. (2003) claim that sustainable design should be:

> *"a creative adaptation to ecological, socio-cultural and built contexts (in that order of priority), supported by credible cohesive arguments"* (Williamson et al. 2003, p. 14).

3.4 Sustainable High-rise (Tall) Buildings

A number of scholars have explored the principles of sustainable high-rise buildings. Al-Kodmany (2015) asserts that the principles of sustainable design for tall buildings should consider the following:

- Passive design strategies;
- Technology;
- Building materials and structural systems;
- Environmental control systems;
- Safety measures;
- Quality in space programming;
- Renewable energy and resources;
- Micro-climates around the tall buildings;
- Construction quality; and
- Management and operations

Al-Kodmany & Ali (2013) suggest a way to deliver sustainable tall buildings in general by considering an overall approach that balances "multiple issues" ranging from "environmental, economic, social, construction, operational and a building's functional adaptability for future market changes". They also stress the importance of context for tall sustainable buildings in relation to providing benefits to the setting and deriving benefits from the context.

For tall buildings to be sustainable, Ali & Armstrong (2010) recommend the following be considered:

- Energy efficiency and functional diversity with an emphasis on multi-functions that combine living, working, retail, and leisure spaces into a single building;
- The relationship between tall buildings and their urban infrastructure; and
- Transportation systems, water and waste distribution, energy use and its impact on the city's physical resources and infrastructure.

Gultekin and Dikmen (2006) cited in Gultekin and Yavasbatmaz (2013) state that sustainable high-rise buildings should have healthy indoor areas with natural ventilation and day-lighting and be comprised of construction materials that are reusable, locally available and that minimise energy use.

Ali and Armstrong (2006) also refer to the process of integration in the case of tall sustainable buildings. According to them integration involves the coordination and design of building systems to work together in a holistic manner in order to maximise energy efficiency and reduce life-cycle operations and maintenance costs (Ali & Armstrong 2006).

According to Ali and Armstrong (2008), sustainable tall buildings essentially aim for design, construction and maintenance practices that obviate the adverse effect of a building on the environment and users. They outlined the following principal design factors that they claim are crucial for achieving sustainable tall buildings: site context, environment, structure and use of materials, energy consumption, use of water, ecological balance and community development. They also add that sustainable design for high-rise buildings entails a holistic view of the entire building operation considering the local and global environment, the availability of renewable and non-renewable resources, community impact assessment and the collaborative input of architects, planners, engineers, social scientists, behavioural scientists and other community based groups.

While the scholars above have argued and proposed principles for sustainable high-rise buildings, none clearly elaborates how these principles and goals can be achieved. This is what will be addressed in this research, but before that, further frameworks that have been developed to address sustainable buildings will be explored in the next section.

3.4.1 Sustainable building assessment frameworks

Building environmental assessment tools emerged in the early 1990s as a way of evaluating building performance across a broad range of environmental parameters, (Hill et al. 2002) as there were concerns about how construction practices could be improved so as to minimise their harmful effects on the natural environment (Holmes and Hudson 2000; Cole 1999). Current discourse on these tools focuses on the holistic notion of sustainability (Todd et al. 2001), as a sustainable building includes not its environmental aspects, but also includes the economic and social aspects. Recent building assessment tools have been formed to assess the success of any building construction in relation to balancing energy, environment and ecology, and considering the social and technology features of the project under consideration (Clements-Croome 2004).

Increasingly, building assessment tools are being used as a means to assess and encourage sustainable practice in the delivery of buildings (Ding 2008; Kaatz et al. 2005). Kaatz et al. (2005) argue that building assessment tools have an important role to play in integrating the premises of sustainability into construction practice, as they provide a means of addressing these issues; however, this will only be possible when these tools efficiently impact the decision-making processes taking place at every stage of the building process (i.e. planning, design, construction, operation and deconstruction).

According to Gibberd (2005), building assessment frameworks should comprise of an overall goal (to make sure that the construction process and buildings are sustainable), objectives (activities and means undertaken to support the goal) and indicators (to measure progress towards attaining objectives). Frameworks lay the groundwork for the development of building assessment tools to help improve the decision making process in achieving sustainable buildings. Shari et al. (2008) identified the need to establish an appropriate building assessment framework for Malaysia because they found that the reasons for the poor progress of the Malaysian construction industry towards addressing sustainability were, primarily, the lack of knowledge and awareness among building stakeholders with regard to sustainability issues. They concluded that an appropriate building assessment framework for Malaysia would not only serve as the basis for an assessment tool but also for an educational mechanism. Shari (2011) developed an assessment framework to address and incorporate sustainable issues in the office buildings of Malaysia. Another framework developed by Akadiri et al. (2012) for the building industry in the United Kingdom provides a brief overview of sustainable principles, strategies and methods, and emphasises the need for an integrated and holistic approach for executing sustainability in building projects. The framework recognises and explicates issues to be considered when using methods for the assessment of environmental performance for existing or new buildings in the following stages: design, construction, operation, refurbishment and deconstruction (Akadiri et al. 2012). The framework, though not an assessment system in itself, is planned to be used in conjunction with, and complimentary to, existing assessment systems or tools such as BREEAM, BEES, LEED, etc. (Akadiri et al. 2012).

The Sustainable Building Assessment Tool (SBAT) and Sustainable Building Lifecycle (SBL) are perhaps the only tools that try to assist the execution of sustainability in the building and construction industry in developing countries, particularly in South Africa. To facilitate the priorities in developing countries, the SBAT tool addresses critical social and economic priorities in developing countries by trying to comprehend and evaluate how buildings can contribute to social and economic sustainability together with environmental sustainability (Gibberd 2002; Gibberd 2005). The Sustainable Building Lifecycle ascertains that an assessment framework, like the SBAT, can be used efficiently (Gibberd 2005).

Tall-Building Projects Sustainability Indicator (TPSI), the only tool designed especially to assess high-rise buildings higher than 20 storeys and regardless of their type), was still under development in 2012, even though its first version was released as an online tool (Nguyen & Altan 2012). The TPSI is strictly a "design" tool and/or a checklist to improve sustainable performance during the design and post construction stages (Nguyen & Altan 2012) of high-rise buildings of any type. In TPSI, the credits are assigned to the 119 issues of assessment criteria for sustainable tall building development. However, it is not clear why certain issues receive more credit than others. It is not explained how the weighting factors can change with the different factors, such as building type, while the assessment criteria remains the same for all building types. The weighting factor of the TPSI is dynamic and depends on climatic zones, the project's social context (whether city-centres or rural areas) and building types.

Although the tool can be considered useful, it would not be efficient in assessing the performance of high-rise residential buildings, as the criteria for residential buildings to be sustainable would be different from that of offices, industrial and institutional buildings. Residential buildings strive to fulfil the needs of the occupants and would generally need to address the occupants' criteria for residential satisfaction. Such criteria for residential satisfaction together with various socio-cultural aspects were not sufficiently addressed in the TPSI assessment criteria. In addition, as regional, social and cultural differences are complicated, the limits are hard to identify; and as there are differences in climatic conditions, income levels, building materials and techniques (Kohler 1999), it is improbable that a group of pre-designed criteria could be set up for use worldwide, without considering the context and making additional amendments (Reijnders & van Roekel 1999).

3.5 Sustainable High-rise Residential Building

Section 3.4 presented different authors' views on sustainable high-rise buildings in general. These views are only generic suggestions for sustainable high-rise buildings (residential or commercial). This section, on the contrary, presents a review of the literature specifically on sustainable high-rise residential buildings.

Cho and Lee (2011) established a conceptual model for sustainable communities in Korean apartment complexes through a questionnaire survey, based on living programs, and physical and social settings. The living program in Cho and Lee's model (2011) which is thought to link the physical and social settings comprises of four action plans: activation of community spaces, activation of community programs, activation of residents' participation, and activation of ecological living and design. Their findings suggest that overall residential environmental satisfaction rises when residents are satisfied with shared community spaces, community programs, and residents' participation in the community.

Zhu and Chiu (2011) discussed planning and design practices for environmentally sustainable high-rise residential buildings by first examining their advantages and disadvantages through a literature review. The strategies recommended by Zhu and Chiu (2011), based on examples from Hong Kong are in line with other researchers mentioned by him, contribute to achieving the environmental sustainability of high rises by minimising the negative environmental impacts of their activities and improving the quality of the living environment of the occupants, including:

- Vertical organisation of land uses

  High-rise residential buildings can be organised with multiple uses – this was also supported by Wood (2007). The different uses that can be incorporated in high-rise buildings consist of at least the following four: residential floors on the top, podium designed as green open and social space for the use of the residents, amenity floors below the podium comprising retail and community facilities, and a public transport interchange below the amenity floors and on the ground floors.

- Energy efficient envelope design

The building envelope must consider the impact on views, day-lighting and natural ventilation while at the same time reduce excessive solar heat gain (Wood 2007). The design of the building envelope has an influence on the energy needed for heating, air conditioning and lighting.

- Optimising spatial configuration

As high-rise residential buildings are usually in a high-density built environment (typically close to one another), this close proximity may reduce air flow around buildings (Chow 2004; Hui 2001; Santamouris et al. 2001), create a heat island effect (Giridharan et al. 2004), obstruct day-lighting (Zhu & Lin 2004; Hui 2001) and the views from the apartments (Planning Department 2006) and reduce visual privacy (Williams et al. 2000). Therefore, the micro-climatic issues such as ventilation are important factors in the planning and design of high-rise buildings, as they can reduce energy demand and hence the adverse impacts such as the use of air conditioners (Kennedy & Thompson 2011). The orientation of the buildings should be verified to improve air and sunlight penetrability, and building heights should be staggered to permit the wind and daylight to penetrate through the project site. The building height should also reduce towards the direction of the view and the prevailing wind. This variation in building height was also recommended by Wood (2007).

- Roof or sky open space and landscaping

Even though adequate open space and green surfaces in the high-density built environment are vital for improving the quality of the living environment (Wood 2007) and improving residents' social lives, for preventing uncomfortable heat island effects and for saving energy (Giridharan et al. 2004; Edwards 1999; Roseland 1998), these spaces are disappearing due to intensive development in the cities. But the building podium or roof can have open space with abundant greenery. Such open space on roofs can provide benefits such as: extra amenity and recreational space for healthy living and social interaction, filtering out particulates through green areas, increase of building insulation and possibly energy efficiency for the top floor (Niachou et al. 2001).

- Provision of balconies

The provision of balconies offers advantages such as extra living space for residents, traffic noise control without compromising views (Griffiths 1999 cited in Zhu & Chiu 2011) and a reduction in solar heat gain through the increased depth of shading.

Kennedy and Thompson (2011), while investigating sustainable practices in subtropical residential towers through a design charrette involving architects, engineers, urban designers, developers, building physicists and social scientists, only focused on the provision of natural ventilation. They claimed that the provision of natural ventilation must be combined with other considerations to achieve overall positive results in terms of comfort, safety, health, privacy and so on, as well as cost-effectiveness considered over the life of the building.

Lee (2007) assessed the sustainability of two super high-rise (buildings above 30 storeys) residential complexes in Korea from the viewpoint of 164 residents, based on a questionnaire survey. The assessment criteria were based on the Korean Green Building Certification Criteria (KGBCC) and the UN Habitat Agenda. He identified ten issues that needed to be improved based on the residents' perspective. Among these ten issues, five items relate to indoor environment, two in each of ecological environment and energy, and one to safety and disaster prevention. While energy saving is considered to be an issue that needs improvement, the study did not include quantitative analysis of energy use in the buildings, nor did it analyse how the building features and occupant behaviour affect energy use.

Wener and Carmalt (2006) put forth the following guidelines using literature review on behavioural and psychological information to create a more holistic approach to sustainable high-rise design:

- The planning should support access to public transportation;
- The building design should allow the occupants to control their environment (temperature, airflow and lighting);
- Day-lighting and natural ventilation should be maximised
- Non-toxic materials should be used;
- Occupants should be given relevant information that will aid and educate them to reduce electricity use, water use and household waste production;
- Energy and water systems should be sub-metered so that occupants know their usage and corresponding costs;
- Grey or black water could be recycled;
- The purchase of energy-efficient appliances and consumer products with low impact packaging should be encouraged; and
- Prompts for conservation and feedback on energy and water usage could be provided to the occupants with real-time, intelligible read-outs of electrical, gas and water usage.

The extensive literature on sustainable high-rise buildings reveals that none, except one study, by Lee (2007) considered a comprehensive approach, consisting of both social and environmental issues pertaining to the sustainable design for high-rise residential buildings in Korea. Cho and Lee (2011) focused only on the social aspects of sustainable high-rise residential buildings, Zhu and Chiu (2011) emphasised only the environmental issues, while Kennedy and Thompson (2011) concentrated on the provision of natural ventilation.

3.6 Satisfaction of high-rise living

As high-rise living is reported to be associated with satisfaction among the occupants, this section attempts to identify the issues that contribute to satisfaction in high-rise living. It is important to identify the issues that contribute to satisfaction in high-rise living because these can add to the factors that may help in promoting socially and environmentally sustainable practices in Dhaka.

Occupants' self-reported satisfaction is a powerful determinant of housing choice (Rapoport 1977) and one of the most frequently used measures of occupant reaction to or liking for a building environment (Herrenkohl 1981 cited in Yuen 2011). This understanding of the occupants' satisfaction is important, because it enables planners and designers of high-rise housing a way of "putting people first" (Church & Gale 2000).

Housing satisfaction in general refers to the level of satisfaction experienced by a person or family within their current housing environment (McCray & Day 1977). Francescato et al. (1979) described residential satisfaction as the occupant's emotional response (whether positive or negative feelings) to the dwelling.

According to Berkoz et al. (2009) and Abrahamson et al. (2013) factors that affect residential satisfaction are environmental quality, attractiveness of the facility, personal issues and their management, accessibility, housing environment, security and relationships with neighbourhoods. However, as this research focuses specifically on high-rise residential buildings, this section tries to outline the factors that are responsible for satisfaction in high-rise living.

Satisfaction, or the lack of it, is one component in the study of occupants' perception of high-rise living (Ali & Armstrong 1995), but it is a crucial one, and it is governed by many factors (Gifford 2007); to treat it as a simple dependent variable is mistaken (Parkes et al. 2002; Birks & Southan 1992). Factors that affect satisfaction include:

- Individual characteristics (Rapoport 1977; Ukoha & Beamish 1997) such as demographic factors, personality, values, expectations, comparisons with other housing and future aspirations (Yuen 2011) and psychological feelings (Rapoport 1977; Ukoha & Beamish 1997);
- Social and cultural influences (Bonnes et al. 1997 cited in Yuen 2011; Varady & Preiser 1998; Newman 1972);
- Physical attributes of the building (Rapoport 1977; Ukoha & Beamish 1997), especially spaciousness, room arrangement/layout and quality of construction (Williamson 1981); floor level and apartment location (Yuen 2005); view (Kennedy et al. 2015; Yuen 2011; Yuen et al. 2006; Yuen 2005; Conway & Adams 1977; privacy (Kennedy et al. 2015; Gifford 2007;Yuen et al. 2006; Yuen 2005; Conway & Adams 1977); quietness (Kennedy et al. 2015; Yuen 2011; Yuen et al. 2006; Yuen 2005; Conway & Adams 1977); open space (Kennedy et al. 2015; Lau 2011; Yuen 2011; Gifford 2007; Coorey 2007); playing space for children (Gifford 2007) and space between building for privacy (Yuen 2011);
- Functional features (Bonnes et al. 1997 cited in Yuen 2011; Canter 1983), services (Onibokun 1974 cited in Yuen 2011) and maintenance (Gifford 2007; Yuen 2011);
- Structural quality (Gifford 1997; Ukoha & Beamish 1997);
- Physical environment (Rapoport 1977; Ukoha & Beamish 1997) such as natural ventilation and day-lighting (Kennedy et al. 2015; Yuen et al. 2006);
- Neighbourhood or area (Onibokun 1974 cited in Yuen 2011) and availability of neighbourhood facilities (Yuen 2011; Gifford 2007; Yuen et al. 2006; Forest & Kearns 2001);
- Social interaction (Yuen 2011; Gifford 2007; Ukoha & Beamish 1997; Rapoport 1977) and efficiency of community space and facilities (Yuen 2011).
- Fire safety (Wong 2011; Yuen 2011; Yuen et al. 2006); and

- Safety and security (Wong 2011; Yuen 2011; Gifford 2007; Yuen 2005).

Rahman et al. (2015) explored the residents' satisfaction with the facilities provided by private real estate developers in Dhaka. Their study, however, does not clarify whether the buildings surveyed were low-rise or high-rise buildings. Their findings suggest that there is a significant relationship between service qualities and occupants' satisfaction when hygienic conditions (decency of the current living area, spaciousness, healthy condition, accessibility of public transport with connections to work, and social and leisure opportunities) play a mediating role. This study also shows that there is a strong relationship between housing costs and occupants' satisfaction when affordability plays the role of a mediator. In addition, the result confirms that community attachment has a weak relationship with the residents' satisfaction level. Although it was not clear whether the investigated buildings were low-rise or high-rise buildings, lessons can be learnt from their findings.

Mridha (2015) investigated the components of residential satisfaction of the dwellers living in developer-built medium-rise (six to nine storeys) apartment buildings in Dhaka. It must be noted that this study is a very recent study, which took place after the researcher of this thesis conducted her field study in 2013. The factors that emerged as very important predictors of residential satisfaction for medium-rise apartments in Dhaka are as follows (Mridha 2015):

- Satisfaction with management and maintenance was found to be the strongest component of residential satisfaction in Dhaka;
- "Neighbourhood" was found to be a strong predictor of satisfaction, with a clean neighbourhood being one of the prime concerns of respondents for satisfaction; and
- The study also confirmed the importance of 'recreation facilities' as a component of residential satisfaction.

Despite the fact that the above studies have identified some components of residential satisfaction mainly for high-rise apartments globally, and to a lesser extent for medium-rise apartments in Dhaka, they do not quantify how these components (such as size of rooms, day-lighting and space between buildings) can contribute to residential satisfaction. The extensive literature review has also not shown whether the noise level in the apartments, design features for the elderly and disabled, household waste management and resource efficiency affect the satisfaction of high-rise living.

3.7 Concerns of High-rise Living

Despite the positive approach to high-rise living, a number of concerns have been associated with it (Yuen 2011). High-rise housing, mainly public housing, is often regarded with caution in many western cities (Yuen 2011). In the USA for instance, the main goal in the erection of public high-rise housing projects was to satisfy the need for housing of that part of the population that could not afford to purchase housing on the private market (Moore 1969). According to Moore (1969), while these high-rise housing projects may have met the housing needs of many low-income families in large cities, they gave rise to certain kinds of problems. It must be noted, however, that the high-rise residential buildings in Dhaka are part of the private sector housing and the dwellers, mainly from the upper and middle-income groups, choose to live in them at their own will.

Nevertheless, it is important to identify the issues that contribute to the concerns in high-rise living because they need to be mitigated in order to promote socially and environmentally sustainable practices in Dhaka. A number of concerns associated with high-rise living from the available literature are presented below:

- Fire safety (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006; Moser 1981; Haber 1977 cited in Yuen 2011);
- Elevator breakdown (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006; Yuen 2005);
- Who the neighbours are (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006);

- Crime in lift such as rape and robbery (Yeh & Yuen 2011;Yuen 2011; Yuen et al. 2006; Haber 1977 cited in Yuen 2011; Zuckerman et al. 1983 cited in Yuen 2011);
- Accidental falls from the high-rise buildings (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006);
- Lack of neighbourhood facilities (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006; Greenberg 1999);
- Power failure (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006; Zuckerman et al. 1983 cited in Yuen 2011; Haber 1977 cited in Yuen 2011);
- Travel time in elevator (Yeh & Yuen 2011; Yuen et al. 2006 Yuen 2011; Yuen 2005; Haber 1977 cited in Yuen 2011; Zuckerman et al. 1983 cited in Yuen 2011);
- Structural safety (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006);
- Crime in corridor (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006; Yuen 2005);
- Building height (Yeh & Yuen 2011; Yuen 2011; Yuen et al. 2006);
- Lack of adequate playing space for children (Yuen 2011);
- Lack of safety (Haber 1977 cited in Yuen 2011; Moser 1981 cited in Yuen et al. 2006; Corporation of London 2002 cited in Yuen et al. 2006; Yuen 2005);
- Children's development (Jephcott 1971 cited in Yuen 2011; Gifford 2007);
- Behavioural problem in children (Ineichen & Hooper 1974 cited in Gifford 2007; Richman 1977 cited in Gifford 2007);
- Less social interaction (Beijing Review 1985 cited in Yuen 2011; Korte & Huismans 1983 cited in Gifford 2007; Forrest et al. 2002; Saegert 1979 cited in Gifford 2007; Zalot & Adams-Webber 1977 cited in Gifford 2007);
- Fear of crime in out-of-range spaces such as long corridors (Mesch & Manor 1998; Adams 1992; Newman 1972 cited in Yuen 2011; Yuen 2005; Newman 1975 cited in Gifford 2007);
- Lack of privacy (Yuen et al. 2006); and
- Suicide (Lester 1994; Clarke & Lester 1989 cited in Gifford 2007).

3.8 Energy Use in High-rise Residential Buildings

3.8.1 Global energy use

As buildings consume energy throughout their whole life cycle, from planning, design, construction, operation and maintenance (Dakwale et al. 2011; Wang & Ma 2009), an improvement in their overall environmental performance by improving their energy efficiency can bring about a reduction in energy demand and carbon emissions, while at the same time saving scarcity in natural resource (Dakwale et al. 2011). Even though buildings consume energy at different stages mentioned above, this research focuses on the energy use of high-rise residential buildings during their operational stage.

According to Hachem et al. (2014), high-rise residential buildings can offer considerable solutions in accommodating the increased density of modern cities while maintaining energy efficiency. However, as there is a relative lack of quantitative studies on the energy consumption of high-rise residential buildings, research on the subject is scarce, the importance of this field notwithstanding.

Worldwide, the residential building sector in general accounts for over one-third of total final energy consumption (IEA 2013), with cooling energy taking up a significant proportion of residential energy use in warm-humid climates. Recent trends in energy demand for cooling is growing rapidly both in high-income countries and emerging economies such as India and China (Isaac & van Vuuren 2009) due to the growing use of air conditioners. Statistics show that air conditioning is the largest single electricity end use in countries with warm-humid climates such as Hong Kong, Singapore and Malaysia. Household electricity use for air conditioning in the residential sector in Hong Kong during a 26 year study period from 1971 to 1996 showed that air conditioning consumed 14.6% of the total electricity used in 1971, and in 1996 this rose to 30.4% (Lam 2000). Another study conducted in Hong Kong in the period 1999-2000 showed that there was a further rise in air-conditioning electricity use, and that it accounted for 46% of the total electricity consumption in the residential sector (Tso & Yau 2003). In Singapore, electricity for air-conditioning accounted for 30% of total electricity consumption in the residential sector in 2005 (NEA 2013).

3.8.2 Energy use in Dhaka

In Dhaka, residential buildings account for more than 50% of the total energy consumption (DESCO 2013). The electricity consumption of the domestic sector in Dhaka has almost doubled from 2005 to 2011 (Mondal & Denich 2010). As the demand for electricity continues to outstrip supply, load shedding has increased in Dhaka (Mondal & Denich 2010), especially during the months of summer. Much of the increased demand for electricity is due to the increased standard of living (Unnayan Shamannay 2006) among higher income groups, with one of the major factors, being the use of air conditioners (Hancock 2006). A study in 2014 showed air conditioners use more electricity than any single appliance in a typical apartment and, in total, air conditioners account for 21% of the total electricity use of the country (UNB 2014). Mourshed (2011) stresses that the impact of increasing demand for cooling energy is likely to affect the energy security and carbon emissions in Dhaka. According to Ahsan (2009), cooling electricity (both fan and air conditioners) accounts for 38% of the total electricity use in apartments, while the remaining 62% is used for lighting and appliances. To date, there has been no study on the electricity use of high-rise residential apartments in Dhaka. Even though it is acknowledged that high-rise residential buildings generally use a high proportion of electricity because of the operation of air conditioners (Khan 2012), at present there is an absence of any kind of clear and verifiable assessment measures to identify what actually contributes to this consumption. Therefore, the purpose of the following sections is to identify the factors affecting both total electricity use and cooling electricity use in high-rise residential buildings worldwide, so that these factors can be tested to see whether they might have any influence on electricity use in Dhaka.

3.8.3 Annual electricity use

Wan and Yik (2004) presented their findings on energy end-use and building characteristics of high-rise residential buildings in Hong Kong. The building characteristics surveyed included apartment size, ratio of the area of living and dining to total apartment size, average number of floor levels, window-to-wall area ratio, and type of fenestration and external shading devices. Though the study presented the findings of building characteristics and energy end-use data, it did not examine the influence of the building characteristics on energy use.

Touchie et al. (2013) examined correlations between building characteristics and actual energy use. The building characteristics included building height, size, vintage, fenestration ratio, glazing type, thermal conductance of glazing and mechanical system details and occupancy type. The study found that there appeared to be no correlation between energy use and building height or size. The building characteristics that exhibited the strongest correlations with energy use were fenestration ratio and boiler efficiency. Energy use was also attributed to differences in building operation.

After an evaluation of the characteristics of actual electrical energy consumption, according to building shape, Choi et al. (2012) showed that plate-type ("I" or "L" shape) buildings used less energy than tower-type buildings did. Choi et al. (2012) however, did not clarify the characteristics and differences between the two shape types.

3.8.4 Cooling electricity use

The majority of the studies pertaining to cooling electricity use in high-rise residential buildings are on Hong Kong, followed by Singapore, as the climate of these countries lead to a significant proportion of air-conditioning electricity consumption (Lam 2000). These studies mainly emphasise on the building envelope. Cheung et al. (2005) and Lam (2000) surveyed the building characteristics of high-rise residential buildings in Hong Kong that can affect heat gain through the building envelope.

The building design characteristics studied by Cheung et al. (2005) were adapted from the study by Lam (2000) and included thermal mass. The building design characteristics studied by Lam (2000) were limited to building orientation, thermal insulation, window area (window-to-wall area ratio), glass type, external shading and colour of the external surface finish. The simulation results for the building characteristics studied by Cheung et al. (2005) show that for a predominantly night-occupied apartment, the strategies on improving the thermal performance of the external walls are more effective than that for windows.

Lam (2000) also used computer simulations to estimate the proportion of the air-conditioning load that was due to heat gain through the building envelope. His findings suggest that the overall building envelope heat gain accounts for 70% of the total cooling load, with 45% for solar heat gain through windows, 24% for external wall conduction and 1% for heat gain through the roof. The study does not indicate the factors that are responsible for the remaining 30% of cooling electricity use, and it also does not consider building shape coefficient[7] (which is also a part of the building envelope) affecting heat gain (Enshen 2005).

Enshen (2005) compared annual cooling and heating needs using computer simulations under different climatic conditions (in 14 cities of China, America and Europe) by varying the shape coefficient from 0.29 to 0.41. As a larger shape coefficient simply specifies that the corresponding outer-surface area of unit building’s volume is larger, regardless of the building height, it does not matter whether the building is a high-rise or low-rise building. He found that both annual cooling and heating energy use increases significantly with the increase of shape coefficients.

[7] The shape coefficient of an apartment can be defined as the ratio of the apartment’s outer-surface area to its inclusive volume (Enshen 2005; Depecker et al 2001).

Bojic et al. (2001) examined the influence of wall insulation and its position in the building envelope on cooling energy in high-rise residential buildings in Hong Kong by using computer simulations. The simulation predictions show that the annual cooling load can decrease up 6.8% by placing a 5 cm thick thermal insulation layer on the inside of the apartments.

Bojic et al. (2002) studied the influence of insulation in internal partitions. They used simulation software to evaluate the annual cooling load (Q) and the peak cooling-load (D) in two high-rise residential flats of different glazing single pane types (clear glazing, tinted glazing, reflective glazing, and tinted and reflective glazing) and different flat orientations. The findings show the dependency of the glazing types for different orientations.

Bojic, Yik, Wan et al. (2002) investigated the effects of shading coefficient of the windows on cooling energy in high-rise residential buildings in Hong Kong by using computer simulations. The simulation predictions specify that a reduction in the annual cooling load can be attained by using thermal insulation to the external walls, without increasing the thickness of the concrete layer, or when the concrete layer was thickened, without using insulation.

Bojic and Yik (2005) investigated the effect of thermal insulation on the envelope and partitions on the annual cooling load of high-rise residential buildings in Hong Kong by using computer simulations. The simulation predictions show that the use of insulations in the envelope and the partitions would be effective in decreasing the annual cooling load by up to 38%, and that it could be reduced to 16% during the peak cooling load, depending on the number and positions of insulation layers in the walls.

Al-Tamimi and Fadzil (2012) studied the influence of four building envelope factors on cooling energy of high-rise residential buildings in Malaysia by using computer simulations: window-to-floor area ratio (WFR), thermal insulation of external wall, glazing type and shading devices. Their results show that compared to the different building envelope factors investigated, thermal insulation of external walls is the best strategy to reduce both cooling energy load and peak cooling load, by a reduction of 10.2% and 26.3 % respectively.

Chua and Chou (2010) studied the suitability of external shading devices and glazing types to improve energy efficiency in high-rise residential buildings in Singapore by using computer simulations. Their results suggest that the presence of an appropriate external shading device together with a careful selection of the right glazing has the possibility to reduce the cooling load of high-rise residential buildings by up to 30%.

Wong and Li (2007) studied the effectiveness of shading devices on cooling energy consumption for east and west windows in high-rise residential buildings of Singapore by using computer simulations. According to them, by adopting 0.3–0.9 metre horizontal shading device, 2.62–10.13% cooling load could be saved. However, this study considered east and west orientations and did not consider parameters such as the width and height of the openings, horizontal shadow angle and vertical shadow angle.

Cho et al. (2014) studied the energy performance and economic feasibility of shading devices in high-rise residential buildings of Korea by using computer simulations. Their results show that 19.7% of annual cooling load can be reduced by horizontal overhang and 17.3% can be reduced by vertical panels.

Hachem et al. (2014) explored the energy performance enhancement methods in multi-storey residential buildings of Canada by using computer simulations. Their results show that in taller buildings (up to 12 storeys), cooling demand increases sharply up to the fourth floor, subsequently moderating and reaching a maximum and finally decreasing gradually in the last but one floor, where there is an increase in cooling load due to the roof effect.

Available literature does not suggest if any study has been conducted to examine the influence of household characteristics (such as household size) and occupant behaviour on electricity use (total or cooling electricity use) in high-rise residential buildings. Two such studies on residential buildings, not necessarily of high-rises, were found that examine the effect of occupant behaviour on total electricity use and cooling electricity use respectively.

In the first study, Ouyang and Hokao (2009) explored the relationship between actual electricity consumption and the lifestyle of households to evaluate the energy saving potential by improving occupants' behaviour in domestic life through energy-saving education. Their findings suggest that improving occupants' behaviour in domestic life through energy-saving education can save household electricity use by more than 10% on average.

In the second study, Yun and Steemers (2011) studied the relative significance of climate, building characteristics (apartment size, number of windows, year of construction and housing type) behavioural and socio-economic parameters on the actual cooling electricity use of residential buildings in the United States. They also demonstrate the effect of direct, indirect and the total effects of these variables on cooling energy use. The study does not specify whether the residential buildings surveyed in the study are high-rise buildings. Yun and Steemers (2011) imply that even though there was a significant relationship between apartment size and cooling energy, the low value of R^2 (0.08) indicates that the direct relationship between apartment size and cooling energy is not conclusive. They conclude that building design characteristics rank low in terms of their influence on cooling energy, and that climate is seen to be the single most significant parameter, followed by behavioural issues (how often air conditioning was used), air conditioning type and finally, socio-economic aspects (household income).

Most available studies also do not imply if they have been directed towards exploring the influence of effective canyon ratio on the energy use in the high-rise residential buildings. Having said so, two such studies have been found: one on a comparative energy consumption analysis between low-rise residential and office buildings, and the other one on the energy performance of a hypothetical low-rise office building. It must however be noted that these two studies do not focus on high-rise residential buildings.

In the first study, Strømann-Andersen and Sattrup (2011) studied the link between canyon ratio and building energy use in Copenhagen by using computer simulations. Six different canyon ratios defined by their height/width (H/W) ranging from 3 to 0.5 were taken. Each canyon was defined only for a 5 storey low-rise building with a height of 15 metres. Simulation tools were used to calculate energy use and the results show that the need for cooling is reduced by an average of 150% with an H/W ratio of 1.5 (canyon width 10 metres) compared to free horizon, and with very narrow canyons (H/W higher than 1.5), the reduction in the need for cooling is not significant. The limitation of this study is that the building height was taken to be constant and it does not allow comparisons to be made for high-rise buildings in an effective canyon.

In the second study, Williamson et al. (2009) examined the influence of canyon ratio on the simulated energy performance of a hypothetical office building in three locations: Adelaide, Glasgow and Sde Boqer. As in the previous study of Strømann-Andersen and Sattrup (2011), the building height in the study by Williamson et al. (2009) was also kept constant (at 14 meters), while the canyon ratio varied from 4 to 0.25. They found that heating energy use decreased in all three locations as the canyon ratio (in this case street width, as height is kept constant) decreases, though not linearly. Conversely, cooling energy use increased as the canyon ratio decreases. Their interpretations reveal that while deep canyons restrict natural ventilation, they provide mutual shading for buildings on either side of the street, resulting in a reduction of cooling energy.

This literature review has discussed how through limited studies, certain building characteristics such as building height, size, age of building, fenestration ratio, glazing type, thermal conductance of glazing and mechanical system details and occupancy type (Touchie et al. 2013) and building shape (Choi et al. 2012) can or might affect total electricity use. Other studies that investigated the influence of building characteristics such as building orientation, thermal insulation, window area, glazing type, shading device and colour of the external surface finish solely focused on cooling electricity use as shown in Table 3-1.

Table 3-1: Summary of key features

Reference	City/Country	Key features
Lam (2000)	Hong Kong	Building orientation, thermal insulation, window area (WWR), glass type, external shading and colour of the external surface finish
Bojic et al. (2001)	Hong Kong	Wall insulation and its position in the building envelope
Bojic et al. (2002)	Hong Kong	Insulation in internal partitions, glazing type and apartment orientation
Bojic, Yik, Wan, et al. (2002)	Hong Kong	Shading coefficient of the windows
Cheung et al. (2005)	Hong Kong	Building orientation, thermal insulation, thermal mass, window area (window-to-wall area ratio), glass type, external shading and colour of the external surface finish
Bojic and Yik (2005)	Hong Kong	Thermal insulation on the envelope and partitions
Enshen (2005)	China, USA, Belgium	Building shape coefficient
Wong and Li (2007)	Singapore	Shading devices consumption for east and west windows.
Ouyang and Hokao (2009)	China	Occupant behaviour
Williamson et al. (2009)	Adelaide, Glasgow, Sde Boqer	Canyon ratio
Chua and Chou (2010)	Singapore	External shading devices and glazing types
Yun and Steemers (2011)	US	Climate, building characteristics (flat size, number of windows, year of construction and housing type) behavioural and socio-economic parameters
Strømann-Andersen and Sattrup (2011)	Copenhagen	Canyon ratio
Al-Tamimi and Fadzil (2012)	Malaysia	WFR, thermal insulation of external wall, glazing type and shading devices.
Hachem et al. (2014)	Montreal	Energy performance enhancement methods in multi-storey residential buildings ranging from low-rise (3-5 floors), mid-rise (6-9 floors) and high-rise (up to 12 floors)
Cho et al. (2014)	Korea	Shading devices

Only two studies, Lam (2000) and Cheung et al. (2005) examined the collective influence of building orientation, thermal insulation, window area, glazing type, external shading and colour of the external surface finish on cooling electricity. Most other studies examined the influence of individual building characteristics on cooling electricity use. Generally speaking, these individual building characteristics mainly focused only on certain aspects of the building envelope of high-rise residential buildings, and have used computer simulations to analyse their effects on the cooling energy use.

The literature review has identified that the influence of household characteristics, household behaviour and canyon ratio on both total and cooling electricity use of high-rise residential buildings specifically have not been examined. Further, the literature review indicates that there is no comprehensive study that investigates the combined influence of climate, design and household characteristics and household behaviour on both total and cooling electricity use, either globally or for the context of Dhaka. This thus demonstrates a need to study the influence of all these factors (climate, design characteristics, household characteristics and household behaviour) that can influence both total annual and cooling electricity use in the high-rise residential buildings of Dhaka.

3.9 Conclusion

This chapter has reviewed the literature according to relevant themes in seven sections. It has firstly reviewed the aspects of sustainable construction, sustainable building, sustainable high-rises and sustainable high-rise residential buildings in the first four sections. This chapter has reviewed the aspects of sustainable high-rise residential buildings from the social and environmental perspectives and has highlighted the key global parameters for sustainable high-rise residential buildings.

It seems that although there are studies that demonstrate different authors' views on sustainable high-rise buildings, these views are not grounded in evidence-based research and are therefore questionable. The extensive review of the literature has identified the gaps in knowledge pertaining specifically to sustainable high-rise residential buildings. The review shows that even though there are global studies that consider the social and environmental aspects of sustainable high-rise residential buildings individually, very few studies have considered a comprehensive approach consisting of both social and environmental issues pertaining to the sustainable design for high-rise residential buildings.

In addition, the studies reviewed did not take into consideration the views of both the stakeholders in the building construction industry and the occupants of the high-rise residential buildings.

The broad global parameters for sustainable high-rise residential buildings that have been identified from the literature are categorised under social and environmental issues as shown in Table 3-2.

Table 3-2: Global parameters for sustainable high-rise residential buildings

Social issues	**Environmental issues**
Social interaction (amongst building occupants, within professionals and between professionals and occupants, community space)	Ecological balance/impact
Planning and design issues (open space, visual privacy, distance between buildings, flexibility in internal arrangement, structure)	Impacts on air, land and water
Education and awareness	Day-lighting, natural ventilation
Safety and security	Construction practice
Employment of local people	Building materials
	Resource management (energy & water)
	Waste management
	Site selection and site development
	Construction practice

In the fifth section, the literature review has identified some aspects of residential satisfaction in high-rise apartments, but not particularly in Dhaka. This demonstrates the need to investigate how the measurable factors, together with the factors that were identified and which are not included in the literature, contribute to the satisfaction of high-rise living in Dhaka.

In the sixth section, the literature review has investigated the concerns related to high-rise living that exist globally. Available literature on high-rise residential buildings in Dhaka, so far, has not explored the occupants' concerns about high-rise living. This demonstrates a need to study the occupants' fears or concerns about high-rise living if such housing is meant to be socially and environmentally sustainable.

Table 3-3 presents the factors that affect satisfaction in high-rise living and the concerns associated with it. The factors for both satisfaction and concerns of high-rise living have been identified as the criteria that would need to be investigated to obtain views of the occupants of high-rise residential buildings. Where possible, quantitative analysis of the factors that contribute to the satisfaction of high-rise living, such as room size, noise level and day-lighting in the various rooms of the apartments would also be examined.

Table 3-3: Summary of satisfaction and concerns of high-rise living

Satisfaction	**Concerns**
Fire safety	Fire safety
Services	Elevator breakdown
	Power failure
	Travel time in elevator
Privacy	Lack of privacy
Space between building for privacy	
Safety and security	Lack of safety
	Crime in corridor
	Crime in lift such as rape and robbery
	Fear of crime in corridors
Structural quality	Structural safety
Quality of construction	
Availability of neighbourhood facilities	Lack of neighbourhood facilities
Social interaction	Less social interaction
Efficiency of community space and facilities	
Social and cultural influences	Who the neighbours are
Floor level and apartment location	Building height
	Accidental falling off from the high-rise
Psychological feelings	Suicide
	Behavioural problem in children
	Children's development
Playing space for children	Lack of adequate playing space for children
Open space	
Adequate room size/spaciousness	
Room arrangement/layout	
Functional features	
Physical environment such as day-lighting, natural ventilation and noise level	
Maintenance	

Lastly, the literature review also investigated the factors that affect energy use, particularly annual electricity use and cooling electricity use in high-rise apartments worldwide. Most of the existing studies were based on computer simulations, without employing actual energy use data and very few studies investigated the combined effects of building characteristics on total and cooling electricity use. Only one study examined the influence of certain building characteristics such as building height, size, vintage, fenestration ratio, glazing type, thermal conductance of glazing and mechanical system details and occupancy type on total electricity use. Two other studies examined the collective influence of building orientation, thermal insulation, window area, glazing type, external shading and colour of the external surface finish on cooling electricity use. Most other studies examined the influence of individual design characteristics on cooling electricity use only. The available literature did not find any studies, globally or in the context of Dhaka, that examined the factors that affect both total and cooling electricity use in high-rise apartments.

Table 3-4 presents the factors that have been identified from previous studies to affect electricity usage. These factors, identified as the design characteristics (floor level, flat size, window area, shading depth, building shape coefficient and effective canyon ratio), climate and occupant behaviour would need to be investigated to examine how they affect total and cooling electricity use in high-rise apartments in Dhaka.

Table 3-4: Summary of factors affecting electricity usage

Factors that affect electricity usage
Climate
Floor level
Flat size
Window area
Shading depth
Building shape coefficient
Effective canyon ratio
Occupant behaviour

4 Methodology and Methods

4.1 Introduction

This chapter describes in detail the steps (outlined in Section 1.7 of Chapter 1) taken to address the research questions. This research uses an evidence-based research paradigm utilising mostly quantitative and limited qualitative research methods. The research aims to formulate strategies for socially and environmentally sustainable practice for high-rise residential buildings in Dhaka that have a higher degree of consensus amongst the stakeholders as these are most likely to be implemented. The findings from the stakeholder questionnaire survey, household questionnaire survey and design characteristics, household characteristics and household practices affecting electricity use are used to formulate these strategies.

4.2 Evidence-based research

Sackett et al. (1996) define evidence-based practice as the

> *"conscientious, explicit and judicious use of current best evidence in making decisions"*(Sackett et al. 1996, p. 71).

Although this definition was first used with regard to evidence-based medicine, it is often prolonged beyond the medical profession and used to define evidence-based practice (Hoffmann et al. 2010). Evidence based practice was further refined (Hoffmann et al. 2010) and it now includes the integration of the best research evidence with clinical expertise and the clients' values and circumstances (Straus et al. 2005).

The evidence-based methodology used in this research is in line with the definition of sustainable design, in particular that proposed by Williamson et al. (2003), as shown in Section 3.2. An evidence-based research methodology was used in this research and was based on information from the following four sources: (1) views of users or occupants, (2) measured data, (3) literature review and (4) expertise of the concerned professionals (Figure 4-1).

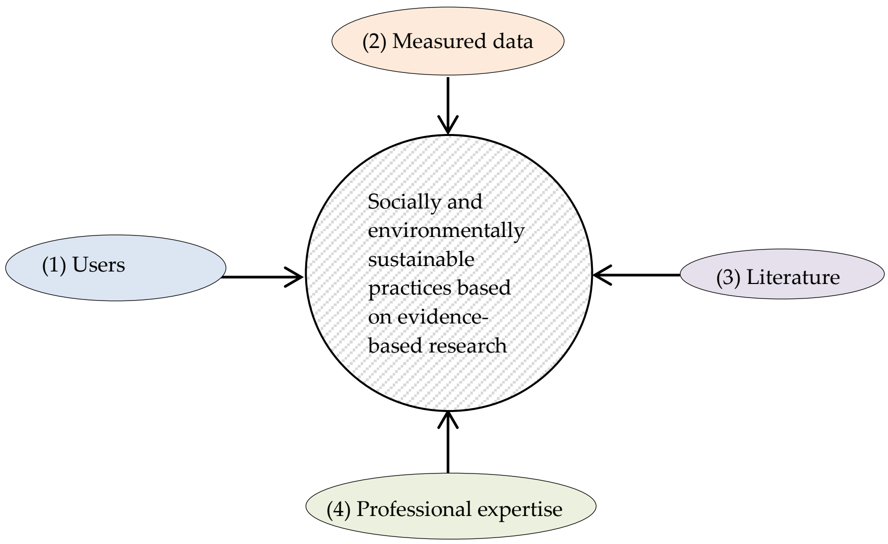


Figure 4-1: Evidence-based research methodology employed in this research

4.3 Research Methods/ Design

In order to develop answers to the research questions using an evidence-based research methodology involving information from four sources, steps 1 to 4 (Figure 4-2) consisting of a literature review (to gather research evidence), survey research involving of questionnaire surveys and field research are the research methods employed in this research. Two more steps comprised of data analysis and presentations of the findings to the concerned stakeholders during the development of the strategies were also part of the research methods. These methods are described in the following sections.

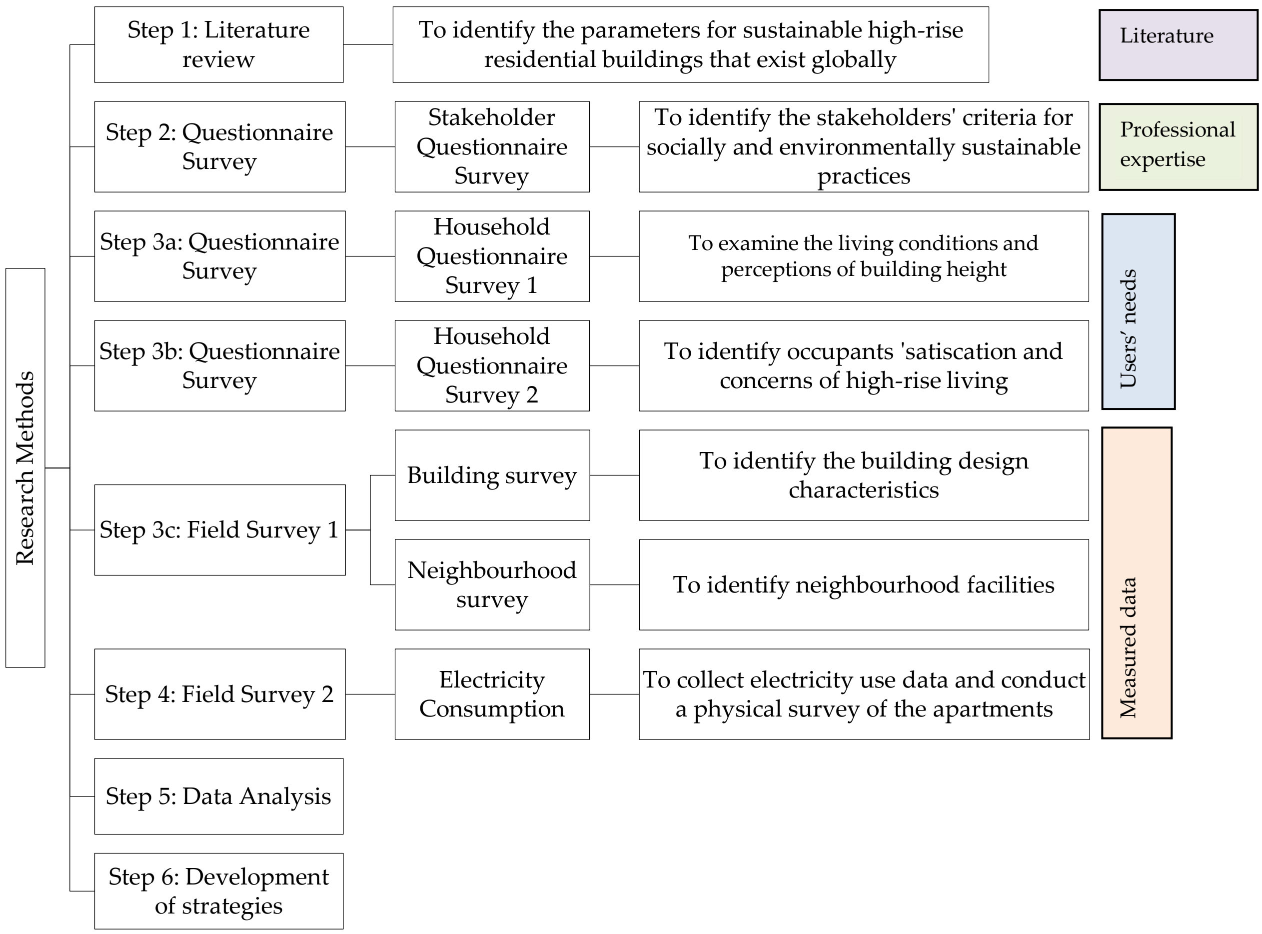


Figure 4-2: Research design involving evidence-based research methodology

4.3.1 Questionnaire Survey 1: Stakeholder Questionnaire Survey

Survey research, in which a questionnaire was the main instrument for collecting data, was conducted among the stakeholders of the building construction industry in Dhaka between March and August 2013 to identify the stakeholders' criteria for socially and environmentally sustainable practices for high-rise residential buildings. The research question addressed through the design of this questionnaire was:

What, according to the stakeholders, are the criteria for achieving socially and environmentally sustainable practices for high-rise residential buildings?

In order to obtain the preferences of the stakeholders, the key criteria (Table 2-4 and 3-2) of achieving sustainable high-rise residential buildings that have been identified from the literature review in Chapters 2 and 3 were used in the design of the questionnaire. The questionnaire survey also included relevant criteria for sustainable buildings developed by Shari (2011); however, as those criteria were for office buildings, adjustments had been made to ensure that this addresses issues for residential buildings. In addition, the questionnaire also sought to explore the stakeholders' preference for building height, open space and the stages at which sustainable issues could be incorporated.

The survey was a self-administered questionnaire and depending on the expressed preference of the stakeholders in responding to the study, the survey was conducted through email, on-line and drop-off method. As closed ended questions are ideal for self-administered questionnaires and reduce the cognitive burden on the respondent (Holyk 2008), the majority of the questions in the questionnaire were closed ended, but included an open-ended format with an ''other'' response alternative to add any other substantive information. It was found that the "other" section was not effective as the respondents did not take the opportunity to expand the answers in the "other" section as has been found in other studies (Salant & Dillman 1994).

As it is important to establish weightings for the various criteria for sustainability in high-rise residential buildings based on the consensus of the stakeholders, the closed-ended questions included questions regarding ratings (least important, slightly important, moderately important, very important, and extremely important) to establish these. A five point Likert scale was designed as the rating scale (1 being least important and 5 being extremely important), as reliability is lower for scales with only two or three points compared to those with more points and the gain in reliability levels off after about 7 points (Krosnick & Presser 2010). As with the reliability of scales, Krosnick and Presser (2010) assert that validity is higher for scales with a moderate number of points than for scales with fewer, indicating that validity is compromised by long scales. A midpoint scale has not been omitted, as eliminating the midpoint will force respondents to choose a point either on the positive side or on the negative side of the scale, causing inaccuracy in measurement (Krosnick & Presser 2010).

Galesic and Bosnjak (2009) investigated the effects of questionnaire length on participation and indicators of response quality in a web survey. They found that the longer the specified length, the fewest respondents started and completed the questionnaire. Furthermore, questions asked later in the questionnaire may produce lower quality data, especially if they have an open-format. However, Dillman (2000) shows that length of mail questionnaires of relevant topics seems to be of less concern among specialised populations.

Hugick and Best (2008), share similar views in that long well-designed mail survey questionnaires that are of interest to the respondents can result in higher response rates, than shorter questionnaires that are not as attractive to respondents. The questionnaire in this research contains seven A4 size pages excluding the participant information sheet and consent form (Appendices A1-A3).

4.3.1.1 Pilot Study

Prior to administering the final questionnaire to the actual sample of respondents, a pilot study was conducted to assess the questionnaire as a whole in order to ensure that it was well understood. The pilot study was undertaken among a small group of respondents, as similar as possible to the target population, who tried to identify potential problems and the viability of the questionnaire by using the three chosen survey methods: on-line, drop-off and email. The objectives of conducting the pilot study were to:

- Test the adequacy of the research design;
- Assess the length of the questionnaire;
- Record the time taken to complete the questionnaire;
- Evaluate if the questionnaire was coherent in structure and layout;
- Assess possible data analysis techniques;

- Ensure there were no problems with the navigation options of the online survey tool; and
- Ensure whether the instructions to the respondents were adequate.

There were eleven stakeholders comprising of five architects, two planners, three engineers and one real estate developer. It should be noted here that the respondents in the pilot study did not represent all the different groups of stakeholders that the questionnaire was originally intended for.

All the completed questionnaires were personally collected from the respondents after one week, representing a 100% response rate. An interview was conducted when the questionnaires were collected from the each respondent in the pilot group. The pilot group was asked how long it took them to fill out the questionnaire. They were asked to critique the questionnaire in order to identify issues of clarity, ambiguities, difficult questions and incoherency. The pilot group was asked for suggestions to improve the questionnaire through possible deletions, additions and modifications. The comments from the pilot group were analysed and some corrections were made to the questionnaire to remove repetitions. The final layout of the revised questionnaire is divided into four sections as described in the next section.

4.3.1.2 Questionnaire context and structure

The stakeholder questionnaire can be found in Appendix A3. The structure of the questionnaire is discussed below:

4.3.1.2.1 Part 1: Background

Questions 1-4 in Part 1 were questions intended to collect information about the respondents' characteristics, including name, contact information, profession and work experience.

4.3.1.2.2 Part 2: High-rise height and open space

Questions 5-6 were questions to identify what were considered desirable in terms of the height of high-rise residential buildings in Dhaka and the percentage of space that must be left open in a site.

4.3.1.2.3 Part 3: Stages at which sustainable issues can be applied

Question 7 was a question to establish the desirable stages at which the sustainable issues should be incorporated in high-rise residential buildings.

4.3.1.2.4 Part 4: Preference of criteria for sustainable high-rise residential buildings

Questions 8 and 9 were questions to identify the stakeholders' preferences on environmental and social criteria for sustainable high-rise residential buildings respectively. These questions were designed to establish what was considered desirable in terms of the ranking of the social and environmental criteria of sustainable high-rise residential buildings.

4.3.1.3 Target population and sampling process

The target population for this survey comprised of stakeholders in the building construction industry in Dhaka, categorised within five professional population frames: planners, architects, real estate developers, engineers and policy makers. This group of stakeholders was considered as the population frame because they were directly involved in the design and construction of high-rise residential buildings in Dhaka, and their perspectives on achieving sustainability in high-rise residential buildings were deemed crucial for this research. The viewpoint of the various stakeholders is important, as the main objective of the survey was to identify if there are any differences of opinion among stakeholders regarding sustainability criteria and to assign ranking/appropriate weighting to each of the finally selected criteria. The selection of the sample under each population frame was based on the criteria described in the following paragraphs.

Professional registered architects in The Institute of Architects Bangladesh (IAB) are grouped in three categories: fellow, member and associate member. In order to qualify as a Fellow Architect, the highest position, he/she must be a regular member of the IAB and must have at least 20 years of work experience. For this research, fellow architects were selected as the first sample frame as they have more experience in the professional field. Samples were compiled from the members' directory of IAB, which had 213 registered regular fellow architects in January 2013 with their email addresses and contact addresses, and working in either the public or private sector.

The second sampling frame was based on registered members of the Bangladesh Institute of Planners (BIP). Professional registered planners in the BIP are grouped in the same way as the IAB. In the BIP, planners can qualify as Fellow Planners when they have been members of BIP for at least two years and have at least ten years work experience. The members' directory of BIP had a list of 130 fellow members (as of January 2013) with email addresses and they were selected as the samples. These members worked in either the public or private sector.

Different branches of engineering in the building construction industry in Dhaka include civil, environmental, mechanical, electrical and so on. However, for the purpose of this research only civil and environmental engineers were selected as the third sample frame because of their experience in the construction of high-rise residential buildings. Professional registered engineers in The Institute of Engineers Bangladesh (IEB) are grouped in the same way as IAB. Fellow Members of IEB must be a member of IEB for at least two years and have at least ten years work experience. In addition, the members' directory also has a list of RAJUK enlisted engineers. Therefore, samples were compiled from the RAJUK enlisted engineers of IEB, which had 326 members. However, as the email and contact address of only 101 engineers was available from the total list of 326 members, these 101 members were compiled as the samples, working in either the public or private sector.

As private land developers are largely involved in the construction of high-rise residential buildings in Dhaka, the fourth sampling frame was based on developers. RAJUK has a list of 10 private apartment developers (as of 2010), registered with

RAJUK. Private land developers and real estate companies not listed with RAJUK were ineligible to obtain approval for developing plots and constructing apartments from July 1 2010 (BSS 2010). These 10 developers were thus compiled as the samples.

In addition to the views of the architects, planners, engineers and developers, the views of policy makers in the building construction industry were also considered important. The policy makers from the Ministry of Housing and Public Works (MOHPW) were considered relevant for this research because of their important role in policy-making, and thus they make up the fifth sample frame. Within the Ministry of Housing and Public Works, the following organisations were selected based on their relevance to this research:

- Public Works Department (PWD);
- Department of Architecture (DOA);
- National Housing Authority (NHA);
- Department of Urban Development (UDD); and
- Housing & Building Research Institute (HBRI).

Each Director from the above five departments was approached for his/her participation in the questionnaire, and they were given a second questionnaire to be distributed to his/her Deputy. Since there were two representatives from each of the five departments of MOHPW, ten policy makers were identified and invited to participate in the questionnaire survey.

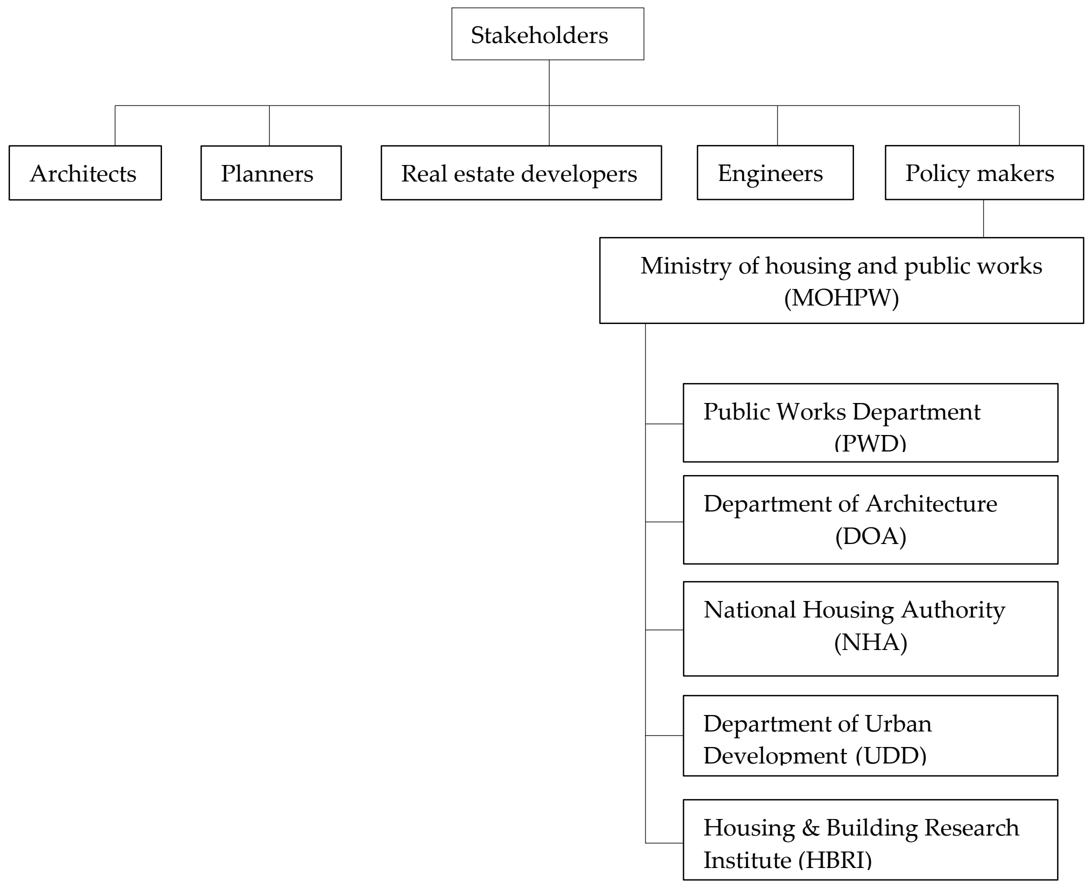


Figure 4-3: Five groups of stakeholders

Once the sampling frame was completed for the five groups of stakeholders (Figure 4-3), no particular sampling method was used to draw a sample from the sample as all of the members identified under each sampling frame were already sampled based on the criteria mentioned in the preceding paragraphs. A comprehensive description of the required sample size of each sampling frame is discussed in the following section.

4.3.1.3.1 Sample size

According to Salant and Dillman (1994) there are recommended sample sizes for different statistical procedures, but no single sample size formula or method is applicable for every research method and statistical procedure. Nevertheless, Salant and Dillman (1994) and De Vaus (2002) assert that the required sample size depends on two important factors: the extent of sampling error that can be tolerated and the degree of diversity in the population with respect to the characteristics of the study.

Dillman et al. (2009) and Fowler (2002) stress that it is the sample size, not the proportion of the population sampled, that affects precision. Table 4-1 shows the suggested size of a completed sample[8] concerning various population sizes and characteristics, as well as various levels of precision.

Table 4-1: Completed sample sizes needed for various population sizes and characteristics at the 95% confidence level, at three levels of precision

Population size	**Sample size for the 95% Confidence Level**					
	±10%		**±5%**		**±3%**	
	50/50 Split	**80/20 Split**	**50/50 Split**	**80/20 Split**	**50/50 Split**	**80/20 Split**
100	49	38	80	71	92	87
200	65	47	132	111	169	155
400	78	53	196	153	291	253
600	83	56	234	175	384	320
800	86	57	260	188	458	369
1,000	88	58	278	198	517	406
2,000	92	60	322	219	696	509
4,000	94	61	351	232	843	584
6,000	95	61	361	236	906	613
8,000	95	61	367	239	942	629
10,000	95	61	370	240	965	640
20,000	96	61	377	243	1,013	661
40,000	96	61	381	244	1,040	672
100,000	96	61	383	245	1,056	679
1,000,000	96	61	384	246	1,066	683
1,000,000,000	96	61	384	246	1,067	683

How to read this table: For a population with 400 members with an evenly split characteristic, a sample of 196 would be needed to make estimates with a sampling error of no more than ±5%, at the 95% confidence level. A "50/50 split" indicates that the population is relatively varied or heterogeneous. An "80/20 split" means it is less varied or homogeneous; most people have a certain characteristic, a few do not. Numbers in the table refer to completed sample sizes needed for various levels of sampling.

Source: Dillman et al. 2009

As the aim of the questionnaire survey was to investigate the perception of the stakeholders of the building construction industry regarding socially and environmentally sustainable practices for high-rise residential buildings in general, rather than to obtain more representative information, a sampling error[9] of ±10% (with an 80/20 split) appeared to be acceptable for this research. Table 4-2 shows the

[8] The "sample" consists of all units of the population that are drawn for inclusion in the survey, whereas, the "completed sample" consists of all of the units that complete the questionnaire (Dillman et al. 2009)

[9] Sampling error is the extent to which the precision of the survey estimates is limited because not every person in the population is sampled (Dillman, et al. 2009)

sample size required for each of the sampling frame, derived according to the information in Table 4-1.

Table 4-2: Sample size of the stakeholders for the stakeholder questionnaire survey

Population group	**Population size** (number in the sampling frame)	**Characteristic of population**	**Completed sample size needed** (number of complete questionnaires needed)	**Number of questionnaires need to be distributed to obtain 30% response rate**
			The actual number of questionnaires distributed to and completed sample obtained from each population is shown in section 4.3.1.5	
Architects	213	80/20 split	47	157
Planners	130	80/20 split	38	127
Engineers	101	80/20 split	38	127
Real estate developers	10	80/20 split	10 (this value cannot be compared to sample size in Table 4-1 as the lowest population size in Table 4-1 starts from 100)	10
Policy makers	10	80/20 split	10 (this value cannot be compared to sample size in Table 4-1 as the lowest population size in Table 4-1 starts from 100)	10
Total	464	N/A	143	431

Note:
An “80/20 split” means that the characteristics of the population is less varied or homogeneous; most people have a certain characteristics while a few do not.

Baruch (1999) conducted a study to investigate the acceptable response rates in academic studies. He concluded that the acceptable response rate should be characteristic of studies directed towards top management (directors, managers, etc.) or representatives of organisations and others such as mid-level managers or conventional population. For the former, he suggested any scholar conducting a study which uses questionnaires that the norm may be 36% ±13%, (i.e. 23- 49%), whereas for most of the other populations, it may be about 60% ± 20% (i.e. 40-80%). As the population targeted for this research was the former group, it was anticipated that the survey would result in at least 30% response rate. Consequently, in order to receive at least 47 completed questionnaires from the architects, it would be required to send 157 (i.e. 47/0.30=157) questionnaires.

4.3.1.4 Questionnaire administration

After conducting the pilot study, an extensive mixed-mode survey design was administered in March 2013 to distribute the self-administered questionnaire. A mixed-mode survey was used because according to Dillman et al. (2009), a mixed mode survey can reduce costs, improve timelines, reduce coverage error, improve response rates and reduce non-response error. The mixed-mode design adopted in this research includes email, on-line and drop-off (and later pick up) methods. Emails were sent to the groups of stakeholders in order to invite them to respond to an online/web survey. A paper questionnaire was also sent to them as an attached document via the email to use a reference in completing the web survey. As providing incentives in the form of token of appreciation can improve response rates (Dillman et al. 2009), a drop-off method was used to deliver the souvenir from Adelaide (key ring) and a paper copy of the questionnaire.

A drop-off (personal delivery) method was also used to deliver the questionnaire to stakeholders for the following reasons:

- People have different preferences for being surveyed and not all respondents would be able to participate in an online survey;
- To provide a souvenir as a token of appreciation; and
- To validate the respondent in the case of online surveys.

A one-month period was allowed before sending emails as a follow up reminder. Two weeks after the follow-up reminder, the respondents were contacted by email and email. In the case of respondents who preferred to fill in the paper questionnaire, a second visit was made to collect the questionnaire.

4.3.1.5 Questionnaire response rate

By mid-July 124 completed questionnaires were received. These 124 valid samples, as shown in Table 4-3, comprise 43 architects (35% of the total), 24 planners (19%), 37 engineers (30%), 10 developers (8%) and 10 policy makers (8%).

Table 4-3: The distribution of the professions of the valid samples

Responses	Population Group					Total Sent	Total Required to Send	Total Returned
	Architect	Planner	Engineer	Developer	Policy Maker			
Sampling frame	213	130	101	10	10			
Needed	47*	38*	38*					
Required to send	157**	127**	127**	10	10		431	
Total Sent	160	130	130	10	10	440		
Total Returned	43	24	37	10	10			124
% returned out of the group	26.9%	18.5%	25%	100%	100%			
% returned out of the total returned	35%	19%	30%	8%	8%			100%
Note	*As referred to Table ** For 30% response rate							

The response rate was 28% (124/440), as only 124 questionnaires were returned out of the 440 questionnaires distributed. This response rate is considered acceptable for a survey aiming to obtain responses from experts in the construction industry (Alreck & Settle 1995; Akintoye 2000).

4.3.2 Questionnaire Survey 2: Household Questionnaire Survey 1

Survey research, in which a questionnaire was the main instrument for collecting data, was conducted among the occupants of the high-rise residential buildings in Dhaka between March 2013 and April 2013. The survey was designed to examine the living conditions (social and environmental), perceptions of building height and to explore the behavioural responses of the occupants of high-rise residential buildings in regards to social and environmental issues therein. The research question addressed through the design of this questionnaire was:

> *What are the current conditions, problems, constraints and achievements of the high-rise residential buildings in Dhaka, Bangladesh?*

In order to evaluate the current conditions, problems and achievements of high-rise residential buildings in Dhaka, the criteria in Table 2-4 of Chapter 2 outlined specially for the occupants were used as a starting point.

The survey was a self-administered questionnaire and included a drop-off method as the administration method. The majority of questions in the questionnaire were closed-ended, but also included an open-ended format by including an ''other'' response alternative to add any other substantive information. A combination of different scales was used in the questionnaire survey. Questions that were asked to rate specific issues usually used a five point Likert scale (1 being poor and 5 being excellent). This household questionnaire contained eight A4 size pages, excluding the participant information sheet and consent form (Appendices B1-B3).

4.3.2.1 Pilot Study

As in the stakeholder questionnaire survey, a pilot study was conducted for this household questionnaire survey. The pilot study was undertaken among the occupants of apartments in buildings with seven to nine floors. The self-administered pilot study was administered using an on-line (SurveyMonkey) survey method, in which the survey link was posted on a social networking website (Facebook). The survey link was kept active in Facebook for a period of two weeks. After two weeks, 50 responses were collected from SurveyMonkey. They were subsequently contacted via telephone to inquire how long it took them to fill out the questionnaire. They were also asked to criticise the questionnaire in order to identify issues of clarity, ambiguities, difficult questions and incoherency. The comments from the pilot group were analysed. Amendments were made to the questionnaire by deleting some questions, adding new questions and regrouping the order of the questions. The final layout of the revised questionnaire is divided into four sections as described in the next section.

4.3.2.2 Questionnaire context and structure

The household questionnaire can be found in Appendix B3. The structure of the questionnaire is discussed below:

4.3.2.2.1 Part 1: Personal characteristics of the respondents:

Questions 1-11 in Part 1 were attribute questions to collect information about the occupants' personal characteristics, including name, address, contact information, age, gender, profession, household size, education, monthly household income, tenure status and length of residency.

4.3.2.2.2 Part 2: Social issues

Questions 12-19 in Part 2 were questions to establish the occupants' perceptions of advantages and disadvantages of living in high-rise residential buildings; occupants' perceptions of building height including perceptions of the present floor level, perception of building height, preferred floor level, fear of building heights and presence of disabled/handicapped person in the apartments.

Questions 20-22 in Part 2 were questions to investigate the monthly rent/mortgage instalments and monthly expense for various utility services; and whether the monthly rent and monthly expense level for the various utility services was high or low.

Questions 23-24 in Part 2 were questions to investigate whether the parking facility was sufficient and to rank the overall condition of the building.

Questions 25 in Part 2 was a question about the presence of community safety and security measures, while question 26 was a question that asked the occupants to rank community safety and security in the buildings.

Questions 27-29 in Part 2 were questions about the maintenance of building services, whether regular inspections were carried out and the frequency of the regular inspection.

Question 30 in Part 2 was a question of public awareness to establish whether the occupants had heard about public awareness programs on energy, water and gas conservation and household waste management.

Question 31 in Part 2 was a question to explore the interaction of the occupants with the architect and developer during the design and construction phase.

Question 32 in Part 2 was a question to obtain information about the physical characteristics of the buildings: total number of floors in the building, total number of apartments and elevators per floor, apartment size, and number of bedrooms, living rooms, dining rooms, kitchens, balconies, bathrooms, servant's room, servant's toilets and storage rooms.

Questions 33-35 in Part 2 were questions about social interaction. Question 33 was a question to find out the importance given by the occupants to the interaction with neighbours. Questions 34 and 35 were questions to identify the place/s of interaction with neighbours and the playing space for children respectively.

Questions 36 and 37 in Part 2 was about open space (whether the buildings occupied the whole land area and whether the occupants wanted more open space). Question 38 was a question to explore if the building/apartment had any green space on the ground floor, balcony and building roof while question 39 was a question to explore visual privacy in the apartments.

Questions 40 and 41 in Part 2 were questions to determine whether the buildings had ramps, handrails in toilets and bathrooms and other necessary design features for the elderly and people with disability and if the elevators in the buildings were large enough to fit in a wheelchair and stretcher.

4.3.2.2.3 Part 3: Environmental issues

Questions 42 to 44 in Part 3 were questions to investigate day-lighting, natural ventilation, air, water and noise pollution in the apartments. Questions 45-49 in Part 4 were questions about household waste management in the buildings, including asking the occupants to rank waste disposal services, whether there was provision of common waste collection in the building complex, provision for separate collection of waste for recycling, whether the occupants had heard of waste separation in 3 bins and how waste was collected from the apartments.

Question 50 was a question about the presence of fire-safety provisions in the buildings, while question 51 was a question that asked the occupants to rank fire safety in the buildings.

Questions 52-58 in Part 3 were questions on resource management to explore water, gas and electricity supplies including the metering systems for electricity, water and gas usage, whether the occupants were aware of water saving techniques, the different water saving devices used in the household and whether rainwater was collected and reused in the building.

4.3.2.2.4 Part 4: Behavioural aspects

Question 59 in Part 5 was a question to determine the occupants' willingness to:

- Have (pay for) more fire security measures;
- Have (pay for) more security measures at the building entrance, apartment and common spaces;
- Have (pay) for energy efficient lighting system;
- Have (pay) for and use water efficient fixtures and fittings;
- Have (pay for) the provision of design consideration for the disabled and elderly people;
- Have (pay for) elevators, large enough to fit a wheelchair and stretcher;
- Have (pay for) the provision of playing space for children;
- Have (pay for) the provision of well-designed interactive community spaces;
- Have (pay for) the provision of Inspections for maintenance purposes;
- Have (pay for) the provision of for gym and game facilities;
- Have (pay for) the provision of more open space;
- Have (pay for) the provision of electrical sub-metering for major consuming devices to monitor electricity usage;
- Have, maintain and pay for the provision of roof gardens;
- Have (pay for) electrical appliances that have energy star ratings;
- Have (pay for) the additional cost for the secondary energy source;
- Collect waste in 3 different bins; and

- Use rainwater and grey water.

Question 60 in Part 5 was a question to study the willingness of the occupants to undertake educational and training programs on

- Fire safety;
- Emergency preparedness during natural disasters (such as earthquake);
- Efficient electricity management;
- Efficient water management;
- Efficient gas management; and
- Efficient household waste management.

4.3.2.3 Target population and sampling process

The target population for this survey were occupants of high-rise residential buildings. Buildings above 7 storeys were considered high-rise buildings. According to a survey by HBRI & CUS (2010), 2150 high-rise buildings (buildings above 7 storeys) were identified in DCC area. Out of these 2150 high-rise buildings, 31.43% (676) were residential. In another study conducted by Seraj (2012) the total number of high-rise apartment units (in buildings of above 7 storeys) was 123,783. Thus, the sampling frame for the household survey was 123,783 apartment units.

High-rise residential buildings in Dhaka are usually difficult to access because of the strict security of the buildings. Unless one knows someone in the apartments of these buildings, access to any apartment or the building itself would be denied. Hence, passive snowball sampling was used as the sampling process in this household survey. Snowball sampling or chain referral is defined as a technique for gathering the research subjects in social research through the identification of an initial subject who is used to provide the names of the other actors (Atkinson & Flint 2004). In this case, the details of the research and researcher were given to the person whom the researcher knew and this person referred the information to other potential contacts with the notion that if the person was interested in participating in the survey, she or he would contact the researcher. According to Atkinson & Flint (2004), these actors open possibilities for an escalating set of potential contacts.

4.3.2.3.1 Sample size

As the aim of this household questionnaire survey was to investigate the living conditions of the occupants of the high-rise residential buildings in general, rather than to obtain more representative information, a sampling error of ±10% appeared to be acceptable. Table 4-4 shows the sample size required for the high-rise apartment sampling frame, derived according to the information in Table 4-1. The sampling frame for the household survey was 123,783 apartment units, which is equivalent to a population size of 100,000, as shown in the shaded region in Table 4-1. The column on population size in Table 4-1 for this sampling frame is assumed to represent the number of apartments (instead of the household size) as the survey was completed by one individual occupant of the apartment. In Table 4-1, a sampling error of ±10% (with 80/20 split) for the population size (household size in this case) is 61.

Table 4-4: Sample size of the respondents for the household questionnaire survey

Population group	**Population size** (number of apartments in the sampling frame)	**Characteristic of population**	**Completed sample size needed** (number of complete questionnaires needed)	**Number of questionnaires need to be distributed to obtain 30% response rate**
Apartments of high-rise residential buildings	123,783	80/20 split	61	203

Note:
An "80/20 split" means that the characteristics of the population is less varied or homogeneous; most people have a certain characteristics while a few do not.

As in the stakeholder questionnaire survey, it was again anticipated that the survey would result in at least 30% response rate. Accordingly, in order to receive at least 61 completed questionnaires from the high-rise apartments, the questionnaires would need to be sent to at least 203 (i.e. 61/0.30=203) apartments.

4.3.2.4 Questionnaire administration

After conducting the pilot study, a survey was administered in February 2013 to distribute the self-administered questionnaire. The survey design adopted here included a drop-off method of the paper questionnaire (and later pick up). As providing incentives in the form of token of appreciation can improve response rates, a souvenir from Adelaide (key ring) was given during the drop-off of the paper questionnaire.

A two-week period was allowed before contacting the apartments as a follow up reminder. Two weeks after the follow-up reminder, the samples were contacted by telephone and a second visit was made to collect the questionnaire.

4.3.2.5 Questionnaire response rate

By mid-May 2013, 117 completed questionnaires were collected from 30 high-rise residential buildings. The response rate was 58% (117/203) as 117 questionnaires were returned out of the 203 questionnaires distributed.

4.3.3 Questionnaire Survey 3: Household Questionnaire Survey 2

The second household questionnaire survey was conducted among the occupants of the high-rise residential buildings between February to March 2014 to identify the factors that lead to satisfaction in high-rise living and identify concerns regarding high-rise living. The research question addressed through the design of this questionnaire was:

> *What are the factors that lead to satisfaction in high-rise living and what are the concerns regarding high-rise living?*

In addition to addressing the above research question, the questionnaire was also designed to identify the importance of the recommended neighbourhood facilities in an area.

The building attributes that are likely to affect residential satisfaction in high-rise residential buildings identified through a literature review in Chapter 3 (Table 3-3) have been used in the design of the second household questionnaire. In addition, the concerns of high-rise living and the recommended neighbourhood facilities, also based on the literature review in Chapter 3 (Table 3-3), have been used in the design of the second household questionnaire.

The survey was once again a self-administered questionnaire and included a drop-off method as the administration method. All the questions in the questionnaire were closed-ended and used a five point Likert scale. This second household questionnaire contains four A4 size pages, excluding the participant information sheet and consent form (Appendices C1-C3).

4.3.3.1 Questionnaire context and structure

4.3.3.1.1 Part 1: Personal characteristics of the respondents

Question 1 in Part 1 was a question that to collect information about the respondents' name, address and contact details.

4.3.3.1.2 Part 2: Satisfaction of high-rise living

Questions 2 in Part 2 was a question to find out the respondents' overall satisfaction of living in the high-rise residential building.

Question 3 in Part 2 was a question to find out the respondents' satisfaction on the following social issues: community safety and security, availability of neighbourhood facilities and regular inspections of the following: fire safety and protection, elevator, electrical installations, plumbing systems, sewage systems, building exterior, building interior and structural components.

Question 4 in Part 2 was a question to find out the respondents' satisfaction on the following design issues: size of bedroom 1, size of bedroom 2, size of bedroom 3, size of living room, size of dining room, size of kitchen, size of toilet, aesthetic appearance of building, room layout plan, interior design, orientation of rooms, efficiency of usable area, design of bathroom facilities, design of kitchen facilities, storage facilities, visual privacy, space for interaction with neighbours, playing space for children, open space around the building, distance between buildings, design features for the elderly and disabled, natural ventilation and efficiency of community space.

Question 5 in Part 2 was a question to investigate the respondents' satisfaction on the following environmental issues: day-lighting in bedrooms, day-lighting in living room, day-lighting in dining room, day-lighting in kitchen, natural ventilation in the rooms, noise level in the rooms, construction quality of the building, structural safety of the building, household waste management, backup power generation, metering systems for electricity usage, metering systems for gas usage, metering systems for water usage, provision of water efficient fixtures , provision of storage and reuse of rainwater.

4.3.3.1.3 Part 3: Concerns of high-rise living

Question 6 in Part 3 was a question to investigate the respondents' concerns about the following: building height, lack of neighbourhood facilities, lack of playing space for children, lack of visual privacy, lack of social interaction, who are the neighbours, emotional stress or mental health difficulties, behavioural problem in children, problems in children's development, accidental falls of family members, leaping from high-rise buildings as suicidal attempts, travel time in elevator, crime in corridor, crime in the elevator, elevator breakdown, fire risk, structural safety, power failure, water crisis, monthly expenses for utility services and rent of apartment.

4.3.3.1.4 Part 4: Importance of having neighbourhood facilities

Question 7 in Part 4 was a question to find out the respondents' chosen level of importance of having the neighbourhood facilities derived from MOHPW and RAJUK (2010).

4.3.3.2 Target population and sampling process

The 117 respondents who had responded in the first household questionnaire survey were contacted to take part in the second household questionnaire survey.

Only 50 out of the 117 respondents in five case study buildings expressed willingness to participate in the second questionnaire survey.

4.3.3.3 Questionnaire administration

The survey design in this second household questionnaire survey is similar to the first household questionnaire survey in which a drop-off method of the paper questionnaire (and later pick up) was used. A one-week period was allowed before contacting the apartments as a follow up reminder. A week after the follow-up reminder, the occupants were contacted by telephone and the questionnaire was collected from their apartments.

4.3.4 Field Survey 1: Building and Neighbourhood Survey

The first field survey was conducted in the 50 apartments of the five the case study buildings whose occupants had expressed the willingness to participate in the second questionnaire survey. During this field survey, the different rooms in these apartments were measured. In addition, the day-lighting and noise in various rooms of these apartments were recorded at daytime using a light meter and sound meter respectively. In addition, the neighbourhoods in an area of approximately 50 acres (20 hectares) from the centre of each of the five case study buildings that housed the respondents of the second questionnaire survey were surveyed to study the 30 neighbourhood facilities recommended by DAP (Detailed Area Plan) for Dhaka.

4.3.5 Field Survey 2: Electricity Use in High-rise Residential Buildings

The second field survey was conducted in the high-rise residential buildings to address the research question:

What are the factors that affect electricity use in high-rise residential buildings?

During the first household questionnaire survey (February- May 2013) described in section 4.3.2, the respondents from the 117 apartments in the 30 buildings and the building authorities (of the 30 buildings) were requested to provide a copy of their electricity use records from January 2012 to December 2012. As electricity use records were considered confidential, only the respondents of 50 out of the 117 apartments in six buildings acceded to this request. In addition, the building authority of one high-rise residential building (122 apartments) and the building authority of one high-rise residential building complex with 4 buildings (170 apartments) together provided the electricity use records of 292 apartments. It must be noted that none of these 292 apartments were part of the apartments that were surveyed during the first household questionnaire survey. Electricity use data were eventually collected from 342 apartments (from the respondents of 50 apartments and from 292 apartments through the two building authorities).

The field survey was carried out in two stages to fulfil the objectives shown in Table 4-5. In the first stage, the electricity use records of 342 apartments in the 8 case study buildings were collected as explained above. The architectural drawings of the 8 case study buildings were also collected during the first stage to study the six design characteristics identified from the literature review in Chapter 3 (Table 3-4). In order to find the canyon ratio, the setback distance around the 8 case study buildings were measured. During the second stage of the field research, the respondents in the 342 apartments were contacted in January 2014 to obtain further information on the following:

- Household characteristics such as household size, number of air conditioners and fans;
- Different household appliances used; and
- Household practices such as air conditioning usage time and preferred set-point temperatures of air conditioners.

Table 4-5: The stages of field survey

Stage	Objective	Sample Size (N)
Stage 1	1. To collect the electricity use data from 342 apartments in 8 case study buildings were collected	342
	2. To collect the architectural drawings of the 8 case study buildings	
Stage 2	1. To study the household characteristics: household size and number of air conditioners and fans in 5 case study buildings	100
	2. Study of household appliances in 5 case study buildings	50
	3. Study of household practices such as air conditioning usage time and preferred set-point temperatures of air conditioners in 5 case study buildings	36

As the respondents of 100 out of the 342 apartments were willing to participate in the second stage of the field research, the household characteristics were obtained from these 100 apartments. Again, out of these 100 respondents, only 50 respondents were willing to provide information on the various household appliances used by them. Finally, out of these 50 respondents, only 36 respondents were willing to provide information on the household practices of air conditioning usage time and preferred set-point temperatures of air conditioners.

4.4 Ethics

As the various surveys in this research involved humans as subjects, ethical approval for "low risk review of research involving people" was obtained in advance from the University of Adelaide's Human Research Ethics Committee. The ethics application form (Appendix D1), Participant Information Sheet for stakeholders (Appendix A1), Standard Consent Form for stakeholders (Appendix A2), Participant Information Sheet for occupants of high-rise residential buildings (Appendix B1), Standard Consent Form for occupants (Appendix B2), Contacts and Independent Complaints Sheet (Appendix D2) and the two questionnaire surveys (stakeholder and first household questionnaire survey) were sent to the Human Research Ethics Committee on 4 July 20. After fulfilling the committee's request for a few minor amendments, the Human Research Ethics Committee approval letter (approval number HP-2012-045) was received on 24 July 2012 (Appendix D3). The second household questionnaire (Appendices C1-C3) which was developed in early December 2013 was sent to the Human Research Ethics Committee on 9 December 2013.

It was made certain that the participants understood the voluntary nature of their participation and that they would not be recognizable in any published results. It was requested of each participant to read and sign the written informed consent form in accordance with the University of Adelaide's ethics requirements before they completed the questionnaire. Each participant was also given the Contacts and Independent Complaints Sheet with the questionnaire for a confidential reporting mechanism if the participants had any worries, complaints or concerns regarding the research project. It should be that noted ethical concerns regarding the photographing of people in the flats and buildings were addressed throughout the research process. The approvals for ethics regarding photographs of people were based on the prior consent from the person/s on their willingness to be photographed.

4.5 Data Analysis

As there were repetitions in some of the questions of the stakeholder questionnaire survey, the data collected were reorganised to better reflect the different criteria under each issue. For instance, while sub-issues on inclusiveness of opportunities, human health and well-being and social interaction were all three independent sub-issues under which there were various criteria in the actual questionnaire, they have become part of the sub-issue on spatial design during the analysis of data. Similarly, questions in the first household questionnaire survey were also reorganised during the data analysis to better reflect the social and environmental conditions in the high-rise buildings surveyed.

All the data from the questionnaire and field surveys were analysed using different statistical methods in SPSS. Details of the data analysis are provided later on as the results are discussed in Chapters 5, 6 and 7.

It must be noted that descriptive statistics were used to summarise data in Chapters 5, 6 and 7. The ranking of different criteria in Chapters 5 and 6 were found by finding the mean, standard deviation and Relative Important Index (RII). To determine the relative ranking of the variables in the questionnaires, the questionnaire responses were transformed to import indices using the equation (Tam 2000):

$$\text{Relative Important Index (RII)} = \sum \frac{\text{w}}{\text{AN}} \ \ldots\ldots \ \textbf{[4-1]}$$

where w was the weighting given to each aspect by the respondent, ranging from 1 to 5 (as the responses were based on a five point Likert scale) in the which “1” was “not important/poor/not satisfied” and “5” was “extremely important/excellent/extremely satisfied”; A is the highest weight (A= 5 in this study); N is the sample size; and RII the Relative Important Index, $0 \leq \text{RII} \leq 1$. Three important levels in the ranking of the variables: high (H) ($0.75 \leq \text{RII} \leq 1$), medium (M) ($0.6 \leq \text{RII} \leq 0.75$) and low (L) ($0 \leq \text{RII} \leq 0.6$) were then transformed from the RII values.

It must also be noted that the significance of the difference in the statistical tests conducted in Chapters 5, 6 and 7 (ANOVA, linear backward regression analysis, cross-tabulation with Chi-square test) is measured by the *p*-value. There are two types of significant difference level, i.e. $p < 0.01$, which indicates a 99% confidence level and $p < 0.05$, which indicates a 95% confidence level (Lane nd). In other words, the *p*-value is the probability of the deductions being incorrect; hence, the lower the *p*-value the more accurate the analysis (de Vaus 2002). However, the p-value in this research is set at 0.05 ($p < 0.05$) as according to Bryman (2008), this is the highest level of statistical significance which is regarded conventional in social research. In addition, de Vaus (2002) revealed that the problem with using 0.01 is that it can cause Type II error (accepting the null hypothesis when it should be rejected) which is especially possible with small samples; hence, for small samples, it is recommended to use 0.05 instead.

4.6 Development of strategies

Once a draft for the strategies for socially and environmentally sustainable practices was prepared, all the 124 stakeholders who had taken part in the stakeholder questionnaire survey were contacted to present the findings to them and consequently have the draft reviewed by them. Out of the 124 stakeholders, only 21 stakeholders expressed willingness to take part in the discussion and review process. The discussion and review process was thus carried out by presenting the findings in the draft to these 21 stakeholders. The discussion took the form of a one-on-one meeting since it was difficult to arrange a focus group discussion with all the 21 stakeholders in the limited time frame. The stakeholders found the strategies useful and illuminating, and some of them had further comments and recommendations. After the feedback and the comments obtained from the 21 stakeholders were analysed, the final draft was prepared by incorporating the comments.

Section II: Results and Analysis

Chapter 5: Views of Stakeholders

Chapter 6: High-rise Living in Dhaka

Chapter 7: Electricity Use in High-rise Apartments

5 Views of Stakeholders

5.1 Introduction

The aim of this chapter is to present the stakeholders' views on sustainable issues and preferences for the criteria for sustainable high-rise residential buildings in Dhaka as identified in Chapter 3. The term 'stakeholders' in this chapter, refers to the professionals who are involved in the building construction industry in Dhaka.

It is anticipated that the ranking of sustainable issues would differ among the different groups of stakeholders as pointed out by Huong and Soebarto (2003) that stakeholders from different groups tend to have different views. Therefore, it is important to explore and understand the difference in views of the different groups of stakeholders before seeking to establish strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka.

The findings of this chapter help in determining the relative importance of the sustainability issues assigned by stakeholders and in formulating the final strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka.

5.2 Methods

As discussed in Section 4.3.1, the views of the stakeholders were investigated through questionnaire surveys. Data were collected through an electronic survey tool (SurveyMonkey) and hard copy. The link to the electronic survey was sent to stakeholders via email.

Descriptive statistics, one-way analysis of variance (ANOVA) and cross-tabulation with a Chi-square test in SPSS (Version 20) are the different analysis methods that were used to analyse the survey data as discussed in Chapter 4.

5.3 Results

5.3.1 Background

Figure 5-1 represents the distribution of the 124 stakeholders by profession who took part in the survey.

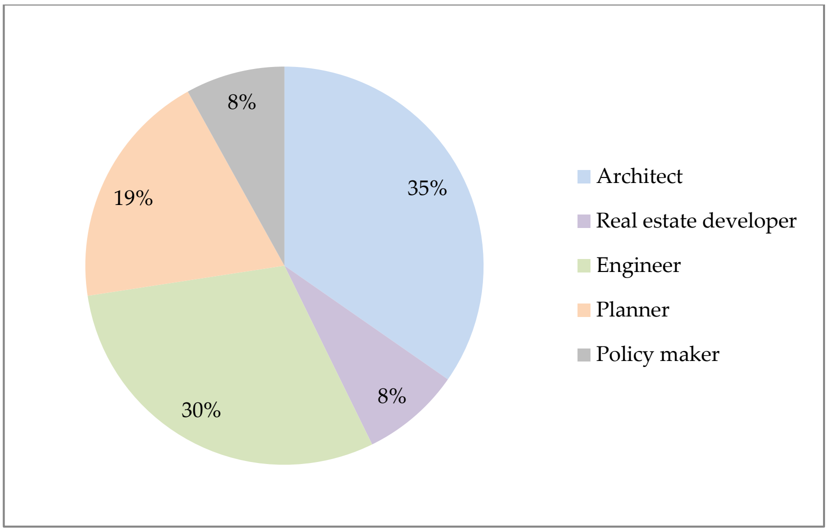


Figure 5-1: Distribution of respondents by profession

In terms of the working experience of the stakeholders, Figure 5-2 shows that about 32% of the stakeholders had a working experience between 11-15 years, and 27% had a working experience of more than 30 years. The results obtained from the survey were based on the opinions of experts in the building construction industry with a minimum working experience of 11-15 years and a mean experience of 21-25 years (SD= 1.6).

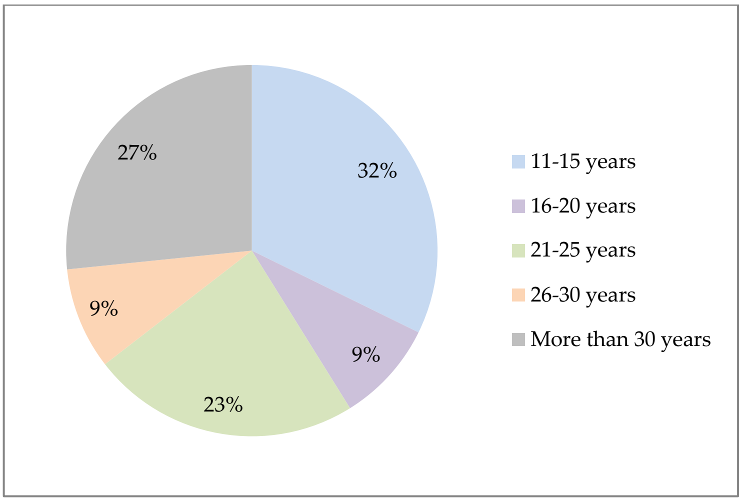


Figure 5-2: Distribution of respondents by years of working experience

5.3.2 Stakeholders' view of building height and open space in high-rise residential buildings

The stakeholders were asked about their views for the height of high-rise residential buildings in Dhaka from 8 given building height groups (where "1" indicated 7-10 storeys,"2" indicated 11-15 storeys, "3" indicated 16-20 storeys, "4" indicated 21-25 storeys, "5" indicated 26-30 storeys, "6" indicated 31-40 storeys, "7" indicated 41-50 storeys and "8" indicated more than 51 storeys). The mean height group of high-rise residential buildings as expressed by the stakeholders was 2.45 (SD=1. 59). The results in Table 5-1 indicate that architects and civil engineers are the only professional groups among the stakeholders who have indicated a preference for the building height of more than 50 storeys for high-rise residential buildings.

Table 5-1: Distribution of building height groups based on the stakeholders' preference

Profession	Min	Max	Mean	SD
Architect	1	8	2.60	1.85
Real estate developer	1	5	2.00	1.41
Civil engineer	1	8	2.74	2.07
Planner	1	5	2.17	1.20
Policy maker	1	4	2.70	1.25

A cross-tabulation with Chi-square test was therefore conducted to find out whether the view of the 8 different building height groups among the five stakeholder groups varied significantly. There was no statistically significant difference at the p

< 0.05 level in preference of building height group for the five stakeholder groups, c^2 (1, N=124) = 21.29, p= 0.81, meaning that all stakeholders had the same preference of building height group for high-rise residential buildings in Dhaka.

The stakeholders were asked about their views for open space (in percentage of the total site) in high-rise residential buildings here. The mean for the percentage of open space in the total site of the high-rise residential buildings as considered appropriate by the stakeholders was 53%, the minimum was 40%, while the maximum was 65% (SD= 6.26).
A one-way between-groups analysis of variance was then conducted to find out whether the preference of the open space among the five stakeholder groups varied significantly. As in the previous case, the stakeholders were divided into five groups (see Table 5-2) according to their professions.

Table 5-2: Descriptive statistics for different groups of professionals and the corresponding mean open space (in percentage)

Analysis	**Findings**	**Stakeholders (5 groups)**	**Mean open space (%)**
Preference of average open space between the six different professional groups	There was a significant difference at the p < 0.05 level for the average open space according to the six professional groups: F (5,118) = 9.11, p= 0.000	Architect (Group 1)	56
		Real estate developer (Group 2)	46
		Engineer (Group 3)	49
		Planner (Group 4)	54
		Policy maker (Group 5)	55

There was a statistically significant difference at the p < 0.05 level in open space for the five professional groups: F (4, 119) = 11, p =0 .00. Post-hoc comparisons using the LSD (Least Significant Difference) test indicated that the mean score (M) for the architect group (M = 56%, SD = 6.69) was significantly different from the real estate developer group (M = 46%, SD = 3.94) and engineer group (M= 49%, SD= 4.21). The mean score for the architect group (M = 56%, SD = 6.69) did not differ significantly from either the planner group (M = 54%, SD= 5.25) or the policy maker group (M = 55%, SD= 4.97). The mean score for the real estate developer group (M = 46%, SD =

3.94) was significantly different from the planner group 4 (M = 54%, SD= 5.25) and the policy maker group (M = 55%, SD= 4.97). Similarly, the mean score for the engineer group (M= 49%, SD= 4.21) was significantly different from the planner group (M = 54%, SD= 5.25) and the policy maker group (M = 55%, SD= 4.97).
The results indicate that architects preferred the mean open space (in percentage of the total site) to be the most, about 56%, while the real estate developers preferred the mean open space to be the least, about 46%.

5.3.3 Stakeholders' scoring of the stages at which sustainable issues can be applied

The stakeholders were asked to indicate at what stage sustainable issues could be applied to the management of high-rise residential buildings (planning, design, building construction, building material production, operation and demotion), where "1" indicated "least suitable" and "5" indicated "extremely suitable".

Table 5-3: Descriptive statistics for stakeholders' scoring of stages

Stages	Min	Max	Mean	SD	RII	Suitability level
Design	3	5	4.62	0.54	0.92	H
Planning	1	5	4.45	0.82	0.89	H
Building construction	2	5	4.22	0.72	0.84	H
Building material production	2	5	4.20	0.68	0.84	H
Operation	1	5	4.05	0.80	0.81	H
Demolition	1	5	3.15	1.24	0.63	L

These stages have been ranked based on the RII as shown in Table 5-3. Out of the six different stages included in the question, the stakeholders gave "high importance" to all the five stages as shown in Table 5-3. Only the demolition stage received "low importance" despite the fact that sustainability issues were considered during the demolition stage. Manual wrecking is a commonly used method for building demolition, while mechanical wrecking is hardly used and explosive charge demolition is not used at all (Fatemi 2012). By using the manual wrecking method, the highest recovery and reclamation potential of demolition waste is possible in Dhaka. Although the process is very labour-intensive, the removal of plaster and masonry works is controlled meticulously to remove each piece of brick in its original form. A group of construction workers breaks the structure and another group (loaders) carry the materials outside of the building and dump the waste in a pre-defined location. The demolition waste is then transported to sites where it can be reused (Saifullah et al. 2009). It seems that since manual demolition is commonly practiced, the stakeholders did not indicate its importance in relation to sustainability.

A cross-tabulation with Chi-square test was then conducted to explore the opinion of the five stakeholder groups on the various stages at which sustainable issues can be incorporated. The results showed that the majority of all profession groups indicated the importance of considering sustainability issues in the planning stage, c^2 (1, N=119) = 37.78, p= 0.01; however, only 20% of the developers indicated the incorporation of sustainability issues to be extremely suitable at the planning stage of a high-rise residential building.

5.3.4 Views of criteria for sustainable high-rise residential buildings

This section refers to Part 4 of the questionnaire, which is the core part of this research. Questions in this section were intended to find out stakeholders' views about the criteria on social and environmental issues identified in Chapter 3. The section on social issues consists of 6 sub-issues (after regrouping during data analysis), while the section on environmental issues consists of 11 sub-issues (after regrouping during data analysis). Each sub-issue had a number of criteria, which the stakeholders were requested to rate. The stakeholders were asked to rate the importance of each criterion based on a five point Likert scale, where "1" indicated "least important", "2" indicated "slightly important, "3" indicated "moderately important", "4" indicated "very important" and "5" indicated "extremely important". In case the stakeholders wanted to suggest additional criteria, there were spaces throughout this part of the questionnaire under the heading "other". However, as there were only a few responses, these criteria were not included in the data analysis.

Descriptive statistics were used to summarise data on the preferences of stakeholders on the various social and environmental criteria by finding the mean, standard deviation and Relative Important Index (RII) (refer to Chapter 4, Section 4.5). Three important levels: high (H) ($0.75 \leq$ RII≤ 1), medium (M) ($0.6 \leq$ RII≤ 0.75) and low (L) ($0 \leq$ RII≤ 0.6) were then transformed from the RII values. In interpreting the result, the criteria under each sub-issue of environmental and social issues that were ranked with RII between 0.75 to 1 (H) by the stakeholders were considered to be important aspects. These aspects would later be incorporated in the final strategies for socially and environmentally sustainable practice for high-rise residential buildings of Dhaka.

In addition to finding out the Relative Important Index for all the criteria under each sub-issue of environmental and social issues, a detailed analysis was also carried out to find out whether the importance of these different criteria varied across the stakeholder groups. However, as no significant differences were noted between the stakeholder groups, subsequent analysis of issues combines all the groups together.

5.3.4.1 Social issues

Under the social issues, there were six sub-issues: culture and heritage, spatial design, community safety and security, maintenance plans, local people and employment, and awareness and education. Each sub-issue comprised of a number of criteria that the stakeholders were asked to rate. A total of 37 criteria were presented under social issues.

5.3.4.1.1 Culture and heritage

The descriptive statistics of the three criteria in the “culture and heritage” sub-issue are shown in Table 5-4. All three criteria received “high importance level” as shown in the shaded region. This is in line with the findings from the literature review where it was revealed that traditional Bengali culture and values such as the formal and informal organisation of space is absent in high-rise residential buildings. The literature review also showed that buildings in general (not high-rise residential buildings) neither conserve heritage value at urban level nor maintain relationship of design with existing streetscape.

Table 5-4: Criteria on culture and heritage

Criteria	Min	Max	Mean	SD	RII	Importance level
Maintenance of heritage value at urban level	1	5	3.94	0.92	0.79	H
Considerations of local cultural values	1	5	3.90	0.81	0.78	H
Relationship of design with existing streetscape	1	5	3.77	0.81	0.75	H

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.1.2 Spatial design

The descriptive statistics of the nineteen criteria in the "spatial design" sub-issue are shown in Table 5-5. Out of the nineteen criteria, fifteen criteria received "high importance level" as shown in the shaded regions.

As the size of rooms in high-rise residential buildings were reported to be small in the literature review (Section 6.3.5.2 later shows that respondents were not satisfied with the size of secondary bedrooms, living and dining rooms) stakeholders gave "high importance" to the criterion on "plan spaces for maximum flexibility" and "adequate room size". Lack of open space (without recommendation on the amount that should be left open), playing space for children, lack of community space, lack of visual privacy are among the problems related to the spatial design of high-rise residential buildings that were reported in the literature review. Criteria for mitigating these problems were given "high importance" by the stakeholders and supported by the dissatisfaction of the respondents shown later in Section 6.3.5.2. Mixed use developments received "high importance" showing the current practice of high-rise developments supported by the findings later in Section 6.3.3.1 (about 40% of the high-rise buildings surveyed were mixed use). Provision of design features for the elderly and disabled, elevators large enough to fit stretchers and adequate storage space received "high importance" demonstrating its importance, supported by the dissatisfaction of the respondents on these features shown later in

Section 6.3.5.2. Though recreational facilities like gym, sports facilities and game room were given “medium importance” by the stakeholders, the occupants are willing to have and pay for the provision of such facilities, as pointed out later in Section 6.3.7

Table 5-5: Criteria on spatial design

Criteria	Min	Max	Mean	SD	RII	Importance level
Plan spaces for maximum flexibility	2	5	4.18	0.78	0.84	H
Elevators capable of fitting a stretcher	2	5	4.17	0.79	0.83	H
Ramps, handrails and other necessary design features for the elderly and people with disability	1	5	4.15	0.85	0.83	H
Adequate open space must be provided	2	5	4.08	0.67	0.82	H
Impacts on visual privacy from adjacent buildings need to be minimised	2	5	3.99	0.67	0.80	H
Adequate room size	3	5	3.94	0.61	0.79	H
Orientation of the building	1	5	3.93	1.05	0.79	H
Visual access to exterior views	2	5	3.92	0.73	0.78	H
Proper size and day-lighting of circulation areas (lobby, hallways, stairs)	2	5	3.90	0.77	0.78	H
Variation in apartment sizes	2	5	3.90	0.77	0.78	H
Spaces for social interaction and playing space for children, for e.g. community spaces, landscaped open space at the ground level, roof garden, etc.	1	5	3.90	0.74	0.78	H
Interaction of the users with the design team during the concept and design development phase to ensure that the occupants’ spatial needs are fulfilled	1	5	3.89	0.94	0.78	H
Mixed-use can be incorporated in the design of high-rise residential buildings	1	5	3.83	0.89	0.77	H
Adequate storage space	2	5	3.80	0.83	0.76	H
Interdisciplinary work among the involved groups from the beginning of the design process to address the spatial needs of the occupants	1	5	3.78	0.90	0.76	H
Maximise plot ratio	1	5	3.69	0.85	0.74	M
Open plan	1	5	3.60	1.05	0.72	M
Design considerations for people with acrophobia (fear of heights)	1	5	3.44	0.93	0.69	M
Recreational facilities like gym, sports facilities and game room	1	5	3.35	0.94	0.67	M

Note :
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.1.3 Community safety and security

The descriptive statistics of the six criteria in the “community safety and security” sub-issue are shown in Table 5-6. Both criteria received “high importance level” as shown in the shaded regions.

Safety and security were pointed out as one of the advantages of living in high-rise residential buildings in Dhaka both in the literature review and household questionnaire survey. In addition, the presence of security measures was observed in 96% of the apartments surveyed as shown later in Section 6.3.2.4. Nevertheless, stakeholders gave “high importance” to the use of various security measures. Safety for children on balconies and roofs received “high importance” as children can be found playing on the roofs as supported by the findings shown later in Section 6.3.3.3.2.

Table 5-6: Criteria on community safety and security

Criteria	Min	Max	Mean	SD	RII	Importance level
Safety for children on balconies & roofs	2	5	4.66	0.64	0.93	H
Safety and security against theft by employing security measures at the building entrance, corridors, staircases, roof and common spaces	3	5	4.31	0.67	0.86	H

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.1.4 Maintenance plan

The descriptive statistics of the three criteria in the “maintenance plan” sub-issue are shown in Table 5-7. All three criteria received “high importance level” as shown in the shaded regions.

The criterion on long term maintenance plan and emergency preparedness planning, though not specific to the context of high-rise residential buildings in Dhaka (found in the literature review), received “high importance” by the stakeholders.

Table 5-7: Criteria on maintenance plan

Criteria	Min	Max	Mean	SD	RII	Importance level
Long term maintenance plan	1	5	3.96	0.78	0.79	H
Emergency preparedness planning/ contingency planning procedures	2	5	3.97	0.84	0.79	H
Training of building operations staff for building maintenance should be made mandatory.	1	5	3.85	0.95	0.77	H

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.1.5 Local employment

The descriptive statistics of the three criteria in the "local employment" sub-issue are shown in Table 5-8. All three criteria received "high importance level" as shown in the shaded region.

None of the criteria focusing on promoting local employment in the design and construction of high-rise residential buildings, specifically, or residential buildings in general were reported during the literature review.

Table 5-8: Criteria on local employment

Criteria	Min	Max	Mean	SD	RII	Importance level
Use experienced and local design team	2	5	4.11	0.79	0.82	H
Use experienced and local contractor	2	5	4.00	0.74	0.80	H
Use experienced and local construction worker	2	5	4.01	0.76	0.80	H

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.1.6 Awareness and education

The descriptive statistics of the nine criteria in the "awareness and education" sub-issue are shown in Table 5-9. Out of the seven criteria, six criteria received "high importance level" as shown in the shaded regions.

The importance of the aspects on increasing occupants' awareness on the effects of natural hazards, education of the construction workers on the importance safety in building construction and making sustainable building principles as part of training courses and accreditation for stakeholders were identified in the literature review for buildings in general.

Despite the importance given by Rahman (2012) to the need of reviewing existing practices to make differences in understanding the forces impacting fragmented communities, declining cities and depleting resources, the stakeholders in this study did gave "medium importance" to the criterion on the participation of the affected community in the development process to avoid conflict.

Table 5-9: Criteria on awareness and education

Criteria	Min	Max	Mean	SD	RII	Importance level
Occupants' awareness on effects of natural hazards should be increased through effective public awareness programs on emergency planning	1	5	4.52	0.72	0.90	H
Occupants' awareness on electricity, water and gas usage should be increased through effective public awareness programs on resource efficiency	2	5	4.19	0.83	0.84	H
Sustainable building principles to be made part of the training courses and accreditation for architects, planners, construction engineers and developers	1	5	4.10	0.94	0.82	H
Education and training of occupants on waste disposal and recycling issues	1	5	4.03	0.83	0.81	H
Construction workers should be educated on the importance of safety in building construction.	2	5	3.98	0.78	0.80	H
Children at the primary level should be taught about resource efficiency	1	5	3.79	1.00	0.76	H
Participation of the affected community in the development process to avoid conflict	1	5	3.13	1.05	0.63	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2 Environmental issues

Under environmental issues, there were eleven sub-issues: site selection, ecological impact, impacts on adjacent properties, impacts on air, impacts on nearby water body, built environment, construction practice, building materials, water management, waste management and energy management. Each sub-issue comprised a number of criteria that the stakeholders were asked to rate. A total of 91 criteria were presented in the environmental issues.

5.3.4.2.1 Site selection

The descriptive statistics of the four criteria in the "site selection" sub-issue are shown in Table 5-10. Out of the four criteria, three criteria received "high importance level" as shown in the shaded regions. All three criteria received "high importance" as evident from the discussion in Sections 2.5.4, 2.6.1 and 2.6.3.

Table 5-10: Criteria on site selection

Criteria	Min	Max	Mean	SD	RII	Importance level
Flooding risk of the site should be assessed	1	5	4.16	0.91	0.83	H
The seismic characteristic of the site should be considered	1	5	4.06	0.90	0.81	H
Agricultural or ecological value of site should be conserved	1	5	3.98	1.00	0.80	H
Redevelopment of existing site rather than working on a new site	1	5	3.41	0.91	0.68	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.2 Ecological impact

The descriptive statistics of the three criteria in the "ecological impact" sub-issue are shown in Table 5-11. Out of the three criteria, two criteria received "high importance level" as shown in the shaded regions. The importance given to these two criteria by the stakeholders follows the discourse in Section 2.5.4.

Table 5-11: Criteria on ecological impact

Criteria	Min	Max	Mean	SD	RII	Importance level
Considerations of damage to existing soil, water bodies and flora and fauna of the site and adjacent land due to construction process	1	5	4.15	1.00	0.83	H
Site that is ecologically sensitive should not be developed and any damage to ecology should be minimised	2	5	3.95	0.86	0.79	H
Conservation of the site's biodiversity	1	5	3.63	0.99	0.73	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.3 Impacts on adjacent properties

The descriptive statistics of the seven criteria in the "impacts on adjacent properties" are shown in Table 5-12. Out of the seven criteria, none received "high importance level". This shows an interesting result considering that in reality, the buildings are so close to each other that they obstruct daylight admittance and wind flow to adjacent properties (Khan 2012).

Another observation can be noted that while the stakeholders gave "high importance" to the criteria for providing visual access to exterior view in Section 5.3.4.1.2 (spatial design issues), they gave "medium importance" to the criteria for minimising impact on views on adjacent properties (Table 5-12). This indicates that the stakeholders are more concerned about their own building and important issues of impacts on adjacent properties are less valued.

Table 5-12: Criteria on impacts on adjacent properties

Criteria	Min	Max	Mean	SD	RII	Importance level
Minimise water pollution during construction of the building	1	5	3.61	1.06	0.72	M
Minimise noise pollution during the construction	1	5	3.41	0.95	0.68	M
Minimise impacts on view	1	5	3.34	1.11	0.67	M
Minimise obstruction of wind to adjacent properties	1	5	3.19	1.05	0.64	M
Minimise obstruction of daylight to adjacent properties	1	5	3.17	1.06	0.63	M
Minimise impacts from site workers' accommodation	2	5	3.06	0.81	0.61	M
Minimise potential glare to adjacent properties	1	5	2.97	0.92	0.59	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority

5.3.4.2.4 Impacts on air

The descriptive statistics of the two criteria in the "impacts on air" sub-issue are shown in Table 5-13. Out of the two criteria, none received "high importance level".

Though industrial emissions from brick kilns are considered as a source of air pollution, stakeholders did not give "high importance" to the criteria for minimising air pollution during construction. Even though it was identified in the literature review that increasing demand for cooling energy is likely to affect carbon emissions in Dhaka, air pollution from all energy used for building operation did not receive "high importance".

Table 5-13: Criteria on impacts on air

Criteria	Min	Max	Mean	SD	RII	Importance level
Minimise air pollution from all energy used for building operation	1	5	3.42	1.02	0.68	M
Minimise air pollution during construction	1	5	3.37	1.16	0.67	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority

5.3.4.2.5 Impacts on nearby water body

The descriptive statistics of the two criteria in the "impacts on nearby water body" are shown in Table 5-14. Only one out of the two criteria received "high importance level" as shown in the shaded region.

Table 5-14: Criteria on impacts on nearby water body

Criteria	Min	Max	Mean	SD	RII	Importance level
Restriction of water contamination in nearby water body during the building operation	1	5	3.96	1.03	0.79	H
Restriction of water contamination in nearby water body during the building construction	1	5	3.62	1.04	0.72	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.6 Built environment

The descriptive statistics of the five criteria in the "built environment" are shown in Table 5-15. Only three out of the five criteria received "high importance level" as shown in the shaded regions.

However, it is interesting to note that reduction of external and internal noise by using sound insulation materials is considered of "high importance" to the stakeholders, even though, minimisation of noise pollution during the construction in Table 5-12 was not considered to be of "high importance".

Table 5-15: Criteria on built environment

Criteria	Min	Max	Mean	SD	RII	Importance level
Location of openings to promote natural and cross ventilation	2	5	4.21	0.64	0.84	H
Adequate daylight in all spaces	2	5	3.94	0.68	0.79	H
Reducing external and internal noise by using sound insulation materials	2	5	3.85	0.66	0.77	H
Glare control	2	5	3.58	0.88	0.72	M
Preventing ingress of external odour	2	5	3.52	0.94	0.70	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.7 Construction practice

The descriptive statistics of the twenty criteria in the "construction practice" sub-issue are shown in Table 5-16. Out of the twenty criteria, fourteen criteria received "high importance level" as shown in the shaded regions. The stakeholders gave "high importance" to the criteria regarding structural and fire safety, safety during building construction processes and compliance to building construction regulations. As shown in the literature review, these factors did not exist in the existing high-rise residential buildings in Dhaka. Other criteria on construction practices that are relatively new for high-rise residential buildings in Dhaka have been given "medium importance", perhaps suggesting lack of awareness or resistance to change from current practice.

Table 5-16: Criteria on construction practice

Criteria	Min	Max	Mean	SD	RII	Importance level
Building design that meets fire safety standards in the BNBC	4	5	4.80	0.40	0.96	H
Practices that avoid construction accidents should be adapted	2	5	4.57	0.68	0.91	H
Compliance to national construction standards and building regulations	2	5	4.48	0.75	0.90	H
Practices that avoid building materials falling off during construction should be adopted	2	5	4.44	0.68	0.89	H
Fire drills must be conducted by responsible fire wardens and management staff at regular intervals.	2	5	4.38	0.66	0.88	H
Ensure adequate structural strength	3	5	4.32	0.86	0.86	H
Provision of easy accessibility of fire fighting vehicles to the building premises	1	5	4.26	0.86	0.85	H

Criteria	Min	Max	Mean	SD	RII	Importance level
Design structure for maximum flexibility	4	5	4.08	0.90	0.82	H
A monitoring unit to ensure safe building construction	2	5	4.09	0.83	0.82	H
Consideration of environmental impact of constructing buildings	1	5	4.00	0.91	0.80	H
Construction workers should be provided with the appropriate safety equipment	2	5	3.98	0.78	0.80	H
Provision of mandatory fire-fighting training for the staff and occupants of high-rise residential buildings	1	5	3.86	0.94	0.77	H
Updating of building construction rules and regulations	1	5	3.83	0.89	0.77	H
Co-ordination about material size with building design to minimise waste	1	5	3.76	0.95	0.75	H
Modular structure of the walls and glazing for ease of construction, minimal material wastage and to support future material reuse	1	5	3.57	1.02	0.71	M
Use of certification systems for construction processes	1	5	3.54	1.17	0.71	M
Repeatability in design and use of standardised prefabricated building components	1	5	3.34	0.92	0.67	M
Design for easy disassembly, reuse or recycling of components	1	5	3.10	0.97	0.62	M
Data gathering processes for monitoring recovery, recycled and landfill materials	1	5	3.10	1.16	0.62	M
Reuse of suitable existing structure on the site as part of the new building	1	5	2.94	1.04	0.59	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.8 Building materials

The descriptive statistics of the eleven criteria in the "building materials" sub-issue are shown in Table 5-17. Out of the eleven criteria, five criteria received "high importance level" as shown in the shaded regions.

Table 5-17: Criteria on building materials

Criteria	Min	Max	Mean	SD	RII	Importance level
Use of durable materials	3	5	4.17	0.61	0.83	H
Building materials that are suitable for the site's climate	2	5	4.07	0.91	0.81	H
Use of local building materials	2	5	4.06	0.80	0.81	H
Use of non-hazardous materials	1	5	4.04	0.92	0.81	H

Criteria	Min	Max	Mean	SD	RII	Importance level
Materials that require minimum cleaning and maintenance	1	5	3.99	0.76	0.80	H
Building materials with low-embodied energy	1	5	3.46	0.97	0.69	M
Reduced use of virgin/new material	1	5	3.26	0.97	0.65	M
Use of recycled building materials	1	5	3.15	1.14	0.63	M
Products and materials with recycled content	1	5	3.10	1.05	0.62	M
Use of salvaged, refurbished or used materials from offsite sources	1	5	2.77	1.07	0.55	M
Reduced use of building materials and finishes from overseas	1	5	2.71	0.96	0.54	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

It is also interesting to note that recycling of building materials is not considered to be of "high importance" by stakeholders, despite the fact that the use of recycled building materials is already practiced in Dhaka (Fatemi 2012) and as Waste Concern Consultants (2010) pointed out that about 25% of the developers reuse construction waste from their projects. It is therefore questionable, as to why the stakeholders did not consider it to be of "high importance" and needs further investigation. Reduced use of building materials and finishes from overseas were not given importance by the stakeholders probably because the affluent occupants usually desire the use of interior finishes such as marble from overseas.

5.3.4.2.9 Water management

The descriptive statistics of the ten criteria in the "water management" sub-issue are shown in Table 5-18. Out of the ten criteria, five criteria received "high importance level" as shown in the shaded regions. It is interesting to note that recycling efforts are not considered to be of "high importance" by the stakeholders, despite the fact that there is a severe shortage of water supply (as already mentioned in Section 2.8.2) and that the occupants are willing to use grey water, as pointed out later in Section 6.3.7.

Table 5-18: Criteria on water management

Criteria	Min	Max	Mean	SD	RII	Importance level
Use of water efficient plumbing fixtures, fittings and appliances	2	5	3.98	0.95	0.80	H
Use of digital water meter in each apartment to monitor water use	1	5	3.94	1.06	0.79	H
Use of runoff water from roof and rainwater harvesting	1	5	3.90	1.05	0.78	H
Minimise water use during construction	1	5	2.80	1.06	0.77	H
Use and management of storm-water for landscaping	1	5	3.80	1.12	0.76	H
Use of recycled water (grey water) for landscape	1	5	3.60	1.10	0.72	M
Use of recycled water (grey water) for flushing in toilets	1.	5	3.38	1.25	0.68	M
Use of recycled water (grey water) for testing of fire-fighting system	1	5	3.23	1.24	0.65	M
Use of recycled water (grey water) for construction	1	5	3.21	1.22	0.64	M
Use of recycled water (grey water) for cooling system	1	5	3.06	1.20	0.61	M

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.10 Waste management

The descriptive statistics of the sixteen criteria in the "waste management" sub-issue are shown in Table 5-19. Out of the sixteen criteria, eight criteria received "high importance level" as shown in the shaded regions. It is interesting to note that as in the case of the criteria on construction practice, criteria on waste management practices that are relatively new in the building construction sector in Dhaka have also not been given "high importance", suggesting lack of awareness or resistance to change.

Table 5-19: Criteria on waste management

Criteria	Min	Max	Mean	SD	RII	Importance level
Designated space for proper collection of waste in the building	1	5	4.06	0.91	0.81	H
Waste bins of appropriate size for organic waste	1	5	4.01	0.91	0.80	H
Safe handling and storage of hazardous waste on site	2	5	4.00	0.82	0.80	H
Garbage chutes in each building	1	5	3.89	1.05	0.78	H
Waste bins of appropriate size for recyclables	1	5	3.83	1.03	0.77	H

Criteria	Min	Max	Mean	SD	RII	Importance level
Redirection of recyclable, recovered resources back to appropriate sites	1	5	3.81	1.06	0.76	H
Waste bins of appropriate size for non-recyclables	1	5	3.77	1.09	0.75	H
Avoiding the use of hazardous materials like volatile organic compounds, timber preservatives, PVC, etc.	1	5	3.84	1.09	0.77	H
Procurement/purchasing policies that support waste avoidance	1	5	3.49	1.03	0.70	M
Construction waste minimization on site by making use of leftover materials and packaging materials	1	5	3.42	0.91	0.68	M
Staff induction on waste management	1	5	3.38	0.90	0.68	M
Construction and demolition waste management program with sorting, reuse and recycling measures	1	5	3.38	1.03	0.68	M
On-site sorting of construction waste for collection and recycling	1	5	3.36	0.94	0.67	M
Collaboration with other building users so that waste can be treated 'regionally'	1	5	3.14	1.20	0.63	M
On-site wastewater treatment systems for grey water and black water	1	5	3.10	1.10	0.62	M
Local composting facility in each building	1	5	2.72	1.05	0.54	L

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.3.4.2.11 Energy management

The descriptive statistics of the eleven criteria in the “energy management” sub-issue are shown in Table 5-20. Out of the eleven criteria, five criteria received “high importance level” as shown in the shaded regions. It is interesting to note that all the criteria on energy management that could be provided by the real estate developers during the construction of the buildings and apartments have been selected by the stakeholders. Whereas, criteria such air conditioning system efficiency and use of energy-star ratings for electrical appliances, on which the stakeholders have no control of, have not been selected by them probably because they are facilities that are not provided by the real estate developers.

Table 5-20: Criteria on energy management

Criteria	Min	Max	Mean	SD	RII	Importance level
Passive design features to reduce energy usage	2	5	3.95	0.82	0.79	H
Use of digital gas meters in each apartment to monitor gas usage	1	5	3.93	1.10	0.79	H
Use of digital electricity meters in each apartment to monitor energy usage	1	5	3.90	0.87	0.78	H
Lighting fixture efficiency	2	5	3.92	0.82	0.78	H
Minimise energy use during building construction stage	1	5	3.78	0.98	0.76	H
On-site secondary power generation systems, e.g. photovoltaic, etc.	1	5	3.64	0.90	0.73	M
Air conditioning system efficiency	1	5	3.56	1.02	0.71	M
Use of electrical sub-meters in each apartment for major consuming appliances to monitor energy usage	1	5	3.52	1.04	0.70	M
Use of energy-star ratings for electrical appliances	1	5	3.46	1.18	0.69	M
Dimmable and /or auto-censored lighting system	1	5	3.24	1.06	0.65	M
Use of wind turbine on roofs to generate electricity	1	5	2.55	1.20	0.51	L

Note:
1= Not needed; 2= Low priority; 3=Medium priority; 4= High priority; 5= Very high priority
Shaded =Selected for the final strategies (0.75≤ RII≤ 1)

5.4 Discussion

Out of the 37 criteria in the section on social issues, 32 criteria were given “high importance” by the stakeholders; whereas, out of the 91criteria in the section on environmental issues, 46 criteria were given “high importance”. More criteria on social issues were given “high importance” by the stakeholders (86%) as compared to the criteria on environmental issue (51%). It appears that the stakeholders placed more importance to social sustainability in high-rise residential buildings in Dhaka as compared to environmental sustainability. Other apparent observations from the findings of environmental criteria (impact on adjacent properties, construction practice and waste management) suggest that the stakeholders are more concerned about their own building, perhaps lack the awareness of sustainable practices and are reluctant to change their current practice to adopt better sustainable practices. The findings of this survey reinforce many findings of other research as described in Section 2.8.1.2.1.

5.5 Chapter Summary

The findings in this chapter indicate that about 36% of the stakeholders define high-rise residential buildings to be those between 7 to 10 storeys high. The mean for the percentage of open space in high-rise residential buildings as considered appropriate by stakeholders was 53%. Out of the six stages at which sustainable issues can be incorporated in the buildings, the stakeholders gave "high importance" to the following (in this order): design, planning, building construction, building material construction, operation. Only the demolition stage received "low importance".

The findings also indicate the stakeholders' views on social and environmental criteria for high-rise residential buildings in Dhaka. The social and environmental criteria that were given "high importance" by the stakeholders (Table 5-21) would be incorporated into the final strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka, which will be discussed in Chapter 8.

Table 5-21: Overall social and environmental criteria

Social criteria
Maintenance of heritage value at urban level
Considerations of local cultural values
Relationship of design with existing streetscape
Plan spaces for maximum flexibility
Elevators capable of fitting a stretcher
Ramps, handrails and other necessary design features for the elderly and people with disability
Adequate open space must be provided
Impacts on visual privacy from adjacent buildings need to be minimised
Adequate room size
Orientation of the building
Visual access to exterior views
Proper size and day-lighting of circulation areas (lobby, hallways, stairs)
Variation in apartment sizes
Spaces for social interaction, for e.g. community spaces, landscaped open space at the ground level, roof garden, etc.
Interaction of the users with the design team during the concept and design development phase to ensure that the occupants' spatial needs are fulfilled
Mixed-use can be incorporated in the design of high-rise residential buildings
Adequate storage space
Interdisciplinary work among the involved groups from the beginning of the design process to address the spatial needs of the occupants
Safety for children on balconies and roofs

Social criteria
Safety and security against theft by employing security measures at the building entrance, corridors, staircases, roof and common spaces
A monitoring unit to ensure safe building construction
Long term maintenance /management plan
Emergency preparedness planning/ contingency planning procedures
Training of building operations staff for building maintenance should be made mandatory.
Use experienced and local design team
Use experienced and local contractor
Use experienced and local construction worker
Occupants' awareness on effects of natural hazards through effective public awareness programs on emergency planning
Occupants' awareness on electricity, water and gas usage should be increased through effective public awareness programs on resource efficiency
Sustainable building principles to be made part of the training courses and accreditation for architects, planners, construction engineers and real estate developers
Education and training of occupants on waste disposal and recycling issues
Construction workers should be educated on the importance of safety in building construction and be provided with the appropriate safety equipment.
Children at the primary level should be taught about resource efficiency
Environmental Criteria
Flooding risk of the site should be assessed
The seismic characteristic of the site should be considered
Agricultural or ecological value of site should be conserved
Considerations of damage to existing soil, water bodies and flora and fauna of the site and adjacent land due to construction process
Site that is ecologically sensitive should not be developed and any damage to ecology should be minimised
Restriction of water contamination in nearby water body during the building operation
Location of openings to promote natural and cross ventilation
Adequate daylight in all spaces
Reducing external and internal noise by using sound insulation materials
Building design that meets fire safety standards in the BNBC (Bangladesh National Building Code)
Practices that avoid construction accidents should be adapted
Compliance to national construction standards and building regulations
Practices that avoid building materials falling off during construction should be adopted
Fire drills must be conducted by responsible fire wardens and management staff at regular intervals.
Ensure adequate structural strength
Provision of easy accessibility of fire fighting vehicles to the building premises
Design structure for maximum flexibility
A monitoring unit to ensure safe building construction
Consideration of environmental impact of constructing buildings
Construction workers should be educated on the importance of safety in building construction.
Provision of mandatory fire-fighting training for the staff and occupants of high-rise residential buildings
Updating of building construction rules and regulations
Co-ordination about material size with building design to minimise waste
Use of durable materials
Building materials that are suitable for the site's climate
Use of local building materials
Use of non-hazardous materials
Materials that require minimum cleaning and maintenance

Environmental Criteria
Use of water efficient plumbing fixtures, fittings and appliances
Use of digital water meter in each apartment to monitor water use
Use of runoff water from roof and rainwater harvesting
Minimise water use during construction
Use and management of storm-water for landscaping
Designated space for proper collection of waste in the building
Waste bins of appropriate size for organic waste
Safe handling and storage of hazardous waste on site
Garbage chutes in each building
Waste bins of appropriate size for recyclables
Redirection of recyclable, recovered resources back to appropriate sites
Waste bins of appropriate size for non-recyclables
Avoiding the use of hazardous materials like volatile organic compounds, timber preservatives, PVC, etc.
Passive design features to reduce energy usage
Use of digital gas meters in each apartment to monitor gas usage
Use of digital electricity meters in each apartment to monitor energy usage
Lighting fixture efficiency
Minimise energy use during building construction stage

While this chapter discussed the views and preferences for the social and environmental criteria of sustainable high-rise residential buildings by the stakeholders in the building construction in Dhaka, the next chapter will explore the experience of the occupants living in high-rise residential buildings, taking into consideration various social and environmental aspects.

6 High-rise Living in Dhaka

6.1 Introduction

This chapter investigates the experience of people living in the high-rise residential buildings in Dhaka in order to better understand the social and environmental aspects of living in such buildings here. The chapter first discusses the social issues of high-rise living in Dhaka, followed by discussions on the environmental aspects. Later, satisfaction and concerns of high-rise living together with the behavioural aspects of the respondents regarding the social and environmental aspects will be discussed.

The social issues of high-rise living in Dhaka are categorised under two groups. In the first group, the social issues include respondents' perceptions of the advantages and disadvantages of living in high-rise residential buildings, respondents' perceptions of building height, socio-economic issues, community safety and security, neighbourhood facilities for high-rise residential buildings, maintenance issues, public awareness and the interaction of the occupants with architects and developers during the design and construction phases. The second group includes spatial design issues comprising the physical and design characteristics of the buildings, social interaction, open space, visual privacy and inclusiveness of opportunity. The environmental issues of high-rise living in Dhaka involved day-lighting and natural ventilation in the apartments, fire safety, air, water and sound pollution, household waste management and resource management.

6.2 Methods

Two surveys were carried out through questionnaires. In the first questionnaire survey, the data on living experience, covering a broad range of social and environmental issues, of a sample of 117 respondents in 30 high-rise residential buildings were collected. The high-rise residential buildings were constructed prior to the onset of the Dhaka Metropolitan Building Construction rules 2008 and they ranged from 7 to 20 storeys.

The second survey was targeted to the respondents of the first survey who showed interest in participating in a more in-depth questionnaire survey, and who also granted permission for a study of their apartments. A total of 50 out of the 117 respondents in five high-rise residential buildings of the first household questionnaire survey agreed to take part in this second survey. All of these five high-rise residential buildings were 3-bedroom apartments. The questions in the second questionnaire survey mainly focused on the satisfaction and concerns involved with living in high-rise residential buildings. During the first field survey, the size of rooms, day-lighting and noise inside the various rooms of the 50 apartments in the 5 case study buildings were measured. The setback distance and the effective canyon ratio on all sides of the five buildings were also measured. In addition, the neighbourhoods around these five buildings were surveyed to study the 30 listed neighbourhood facilities.

Descriptive statistics, one-way analysis of variance (ANOVA), linear regression analysis and cross-tabulation with a Chi-square test with SPSS (Version 20) are the different analysis methods used in this chapter. Descriptive statistics were used to summarise data on the various social, environmental aspects of high-rise living, the satisfaction, concerns and behavioural aspects of the respondents by finding the mean, standard deviation and Relative Important Index (RII) (refer to Chapter 4). This is followed by a section which reflects on the possible interpretation of the results.

6.3 Results

6.3.1 Personal characteristics of the respondents

The majority (62%) of the respondents were male (62%) as against 38% who were female as shown in Table 6-1. Most (38%) of the respondents were between 26 and 46 years, while another large group of respondents (36%) was between 46 and 65 years. The mean household size of the 117 apartments surveyed was 4.5, while the maximum number of occupants was 7. The age distribution of the occupants in the apartments can be seen in Table 6-1. A large number of the respondents (59%) were undergraduates.

Table 6-1: Personal characteristics of the 117 respondents

Demographic variables	**Subcategories**	**Frequency**	**Percentage**
Gender of respondents	Male	73	62
	Female	44	38
Age of respondents	18-25 years	17	15
	26-45 years	45	38
	46-65 years	42	36
	More than 65	13	11
Age of all occupants in the apartments	0-4 years	34	6.4
	5-9 years	34	6.4
	10-14 years	50	9.4
	15-24 years	107	20.2
	25-34 years	96	18
	35-44 years	68	12.8
	45-59 years	84	15.8
	60-69 years	47	8.9
	70-80 years	10	1.9
	Above 80 years	1	0.2
Education of respondents	Up to Higher Secondary School	23	20
	Undergraduate	69	59
	Postgraduate	25	21
Socio-economy status	Upper middle (US$320-641)	21	18
	Lower upper (US$642-1282	59	50
	Upper upper (Above US$1282)	37	32
Profession of respondents	Businessperson	35	30
	Housewife	20	17
	Student	16	14
	Doctor	10	9
	Government service	9	8
	Engineer	8	7
	Lawyer	6	5
	Architect	5	4
	Teacher	5	4

Demographic variables	Subcategories	Frequency	Percentage
	Banker	3	2
Tenure status	Rent	37	32
	Own	80	68
Length of residency	1-5 years	55	47
	6-10 years	50	43
	11-15 years	7	6
	Over 15 years	5	4

Although it was difficult to ascertain the income of the respondents due to the fact that income is considered as a highly sensitive issue and people deliberately tend to answer inaccurately, the results revealed that about 18% of respondents claimed that they belonged to the "upper middle income group" with a monthly household income of US$320-641. The majority (50%) of respondents claimed that they belonged to the "lower upper income group" with a monthly household income of US$642-1282. The remaining 32% claimed that they belonged to the "upper upper income group" with a monthly household income of above US$1282. None of the respondents claimed to belong to the "lower middle income group" or "lower income group".

A majority (30%) of the respondents were businessperson, while a few were doctors (9%), government employees (8%), engineers (7%), lawyers (5%), architects (4%), teachers (4%) and bankers (2%). The results also revealed that the majority (68%) of the respondents were the owners of the apartments as against 32% who were renters. It was also observed that the majority (47%) had lived in the apartments between one and five years and (43%) had lived in the apartments between six to ten years.

6.3.2 Social issues

6.3.2.1 Respondents' perceptions of advantages and disadvantages of living in high-rise residential buildings

6.3.2.1.1 The advantages of living in high-rise residential buildings

Around 68% of the respondents reported having some of the advantages of living in high-rise residential buildings. Figure 6-1 presents the different advantages of living in high-rise residential buildings as perceived by the respondents, living across different floor levels: 1-6, 7-10, 11-15 and 16-20. Better natural ventilation, ample day-lighting, better security and less noise were among the most frequently cited advantages of living in high-rise residential buildings. It must be noted that as the question on advantages of living in high-rise residential buildings was open-ended, the most frequent responses were coded and the responses have been presented using frequency distributions.

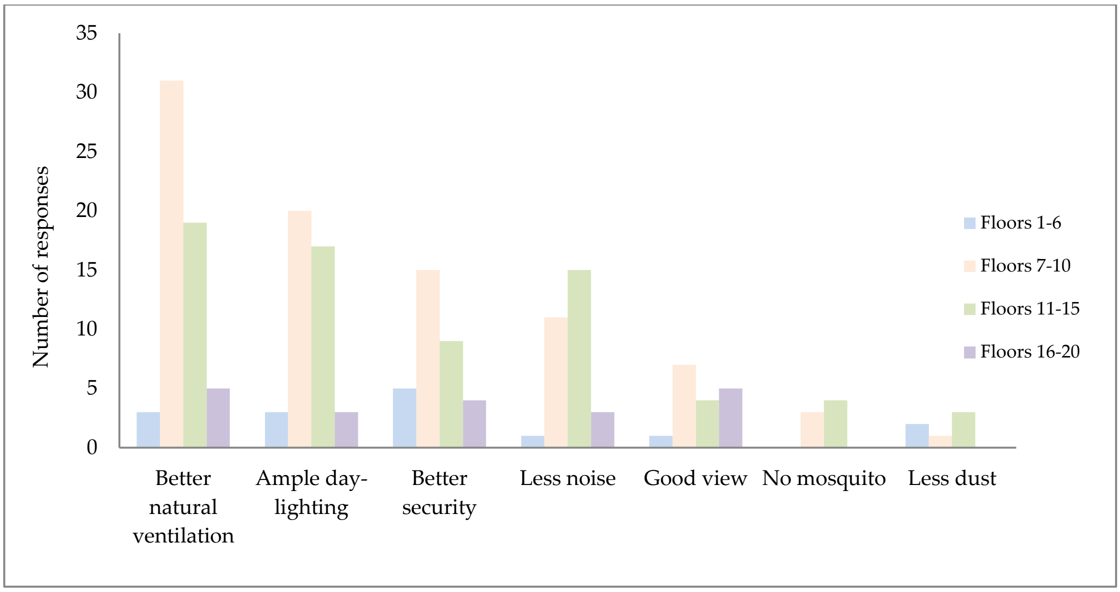


Figure 6-1: Advantages of high-rise living across different floor categories according to the 117 respondents

It is interesting to note that compared to the respondents on different floor categories, it is the respondents on the floors 7-10, followed by those on floors 11-15 who have mostly reported on the different advantages of high-rise living.

6.3.2.1.2 The disadvantages of living in high-rise residential buildings

Around 23% of respondents reported that they faced disadvantages of living in high-rise residential buildings. Figure 6-2 presents the different disadvantages of living in high-rise residential buildings as perceived by the respondents also living across the different floor levels: 1-6, 7-10, 11-15 and 16-20, similar to the previous case. Lack of safety during fire, fear of structural safety and difficulty in using the stairs when the elevators are not working and when there is no electricity were among the most frequently cited disadvantages of living in high-rise residential buildings. These disadvantages of high-rise living are compared to the general concerns of high-rise living in Section 6.3.6.

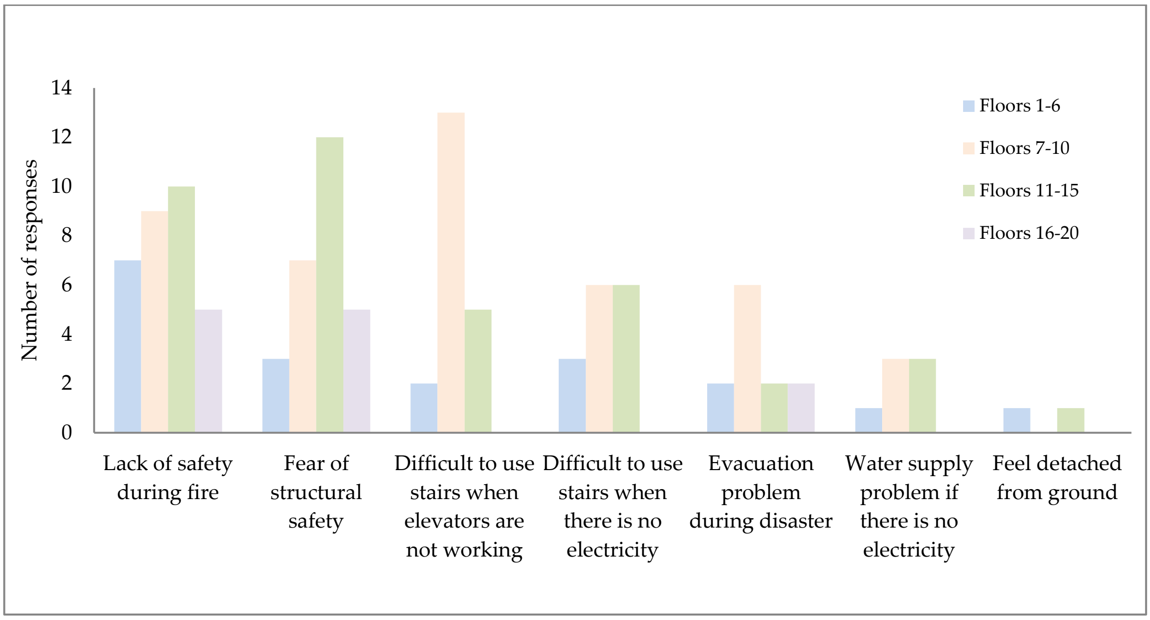


Figure 6-2: Disadvantages of high-rise living across different floor categories according to the 117 respondents

It is evident from Figure 6-2 that the lack of safety in the event of possible fire is a predominant disadvantage of high-rise living regardless of the floor groups. It is interesting to note that respondents living on the highest floor levels (16-20) report only on disadvantages regarding fire safety, structural safety and evacuation problems.

6.3.2.2 Respondents' perceptions of building height

6.3.2.2.1 Perception of present floor level

The number of floors of the buildings that were surveyed varied from 7 to 20. Table 6-2 shows that the majority of respondents who live on the lower floors (1-5) indicated that they felt that either they did not live high enough or were not concerned about the floor level. The majority of the respondents living on floors 6-15 indicated that where they lived was just right, whereas quite a number of respondents on floors 16-20 indicated that their present floor level was too high.

Table 6-2: Perception of present floor level (%) according to the 117 respondents

Present floor level	Too high	Not high enough	Too low	Just right	Don't care/never thought about it	Total
1-5 floor	0	22	0	0	78	100
6-10 floor	0	13	20	47	20	100
11-15 floor	5	17	0	67	11	100
16-20 floor	44	0	0	56	0	100
21-25 floor	0	0	0	0	0	100

It is worth noting that only 9% of the respondents reported having a fear of heights, and only 7% of the respondents reported the presence of disabled/handicapped persons in their apartments.

6.3.2.2.2 Perception of building height

Table 6-3 illustrates that about 96% of respondents defined buildings between 11-15 storeys as tall buildings and 4% defined them as very tall buildings. About 64% of the respondents considered buildings between 16-20 storeys as very tall buildings.

Table 6-3: Perception of building height (%) according to the 117 respondents

Building height	Not a tall building	Tall building	Very tall building	Total
1-5 storey	100	0	0	100
6-10 storey	64	36	0	100
11-15 storey	0	96	4	100
16-20 storey	0	36	64	100
21-25 storey	0	0	100	100

6.3.2.2.3 Preferred floor level

The majority (about 34%) of respondents preferred to live on floors between 11 and 15, as illustrated in Table 6-4.

Table 6-4: Preferred floor level (%) according to the 117 respondents

Preferred floor level	Percentage
1st-5th floor	2
6th-10th floor	22
11th-15th floor	34
16th-20th floor	28
21st-25th floor	14

6.3.2.3 Socio-economic issues

In response to the question to whether the monthly rent was low or high, the mean was 2.64 for responses that were coded as follows: "1" indicated "slightly low", "2" indicated "about right", "3" indicated "high", "4" indicated "very high" and "5" indicated "extremely high". This value for the mean showed that the rent level varied between "about right" to "high".

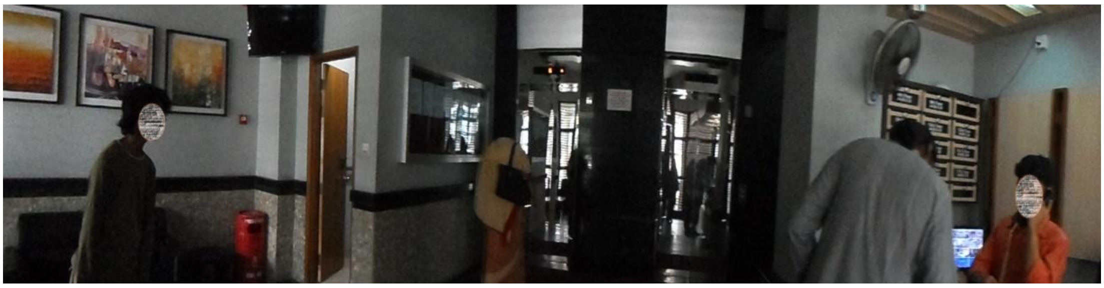
In order to study the relationship between household income and rent level (whether the rent was high or low) a cross-tabulation was conducted in SPSS. A statistically significant difference (p= 0.02) was observed in the response between household income and rent level (whether the rent was high or low). Around 25% of respondents (N= 36, only respondents who rent the apartments have been selected) who had a household income between US$320-641 and US$642-1025, expressed that the rent they paid was high (89%). About 22% of respondents with a household income between US$1026-1282 expressed the rent being both about right (50%) and high (50%). Around 28% of respondents with a household income above US$1282 expressed the rent being about right (70%). It can thus be concluded that respondents with a higher income category voiced the rent as being about right.

In order to study the influence of different floor groups (Group 1: 1-6; Group 2: 7-10; Group 3: 11-15; Group 4: 16-20) on the rent of the apartments, a cross-tabulation was performed in SPSS. No statistically significant difference (p= 0.45) was observed in the response between the respondents of floor groups and the rent level (whether the rent was high or low). This shows that the rent of the apartments on higher floors was not necessarily higher than that of the lower floors.

The mean monthly expense for the various utility services was US$34. In response to the question on whether the monthly expense for the various utility services was low or high, the mean was 4.15, for responses that were coded as follows: "1" indicated "slightly low", "2" indicated "about right", "3" indicated "high", "4" indicated "very high" and "5" indicated "extremely high". This mean shows that the monthly expense level for utility services varied between "very high" to "extremely high". No statistically significant difference (*p*= 0.65) was observed in the response between household income and if the expense on utility costs was high or low.

6.3.2.4 Community safety and security

About 96% of respondents reported the presence of safety and security measures to control the entry of the visitors and unknown persons in the buildings. They perceived community safety and security in the buildings and apartments to be adequate (mean= 3.28, on a five-point Likert scale, where "1" indicated "poor" and "5" indicated "excellent"). Out of the 30 buildings surveyed, only 4 buildings had the provision for monitoring safety and security using close circuit cameras. Figure 6-3a shows the reception space in a high-rise residential building lobby where the building security staff calls the respondents of the apartment using the intercom to inform the respondents of any visitors. The visitor has to sign in on a register with his/her details before being allowed to proceed. Figure 6-3b shows the use of close circuit cameras in a building for monitoring community safety and security.



(a) Foyer with security staff

(b) Presence of CCTV in foyer

Figure 6-3: Community safety and security

A cross-tabulation with Chi-square test was conducted to find out the relationship between the respondents' perceived community and security in the building and the provision of safety and security measures for users to access the building. A statistically significant difference was found between the responses, c^2 (1, N=111) = 29.89, *p*= 0.000, illustrating that in 4% of the buildings that did not have the provision of safety and security measures for users to access the building, 50% of the respondents expressed the security level in the building to be "poor". Conversely, in 96% of the buildings with the provision of safety and security measures for users to access the building, 58% of the respondents expressed the security level in the building to be "moderately good". This expresses the need to have even better safety and security measures for users to access the building.

6.3.2.5 Neighbourhood facilities for high-rise residential buildings

The respondents of the 50 apartments in the five case study buildings were asked to rank the importance of the 30 neighbourhood facilities recommended by DAP as discussed in Chapter 2. The responses of the respondents were based on a five point Likert scale, where "1" indicated "not important" and "5" indicated "extremely important". Table 6-5 presents the descriptive statistics together with the Relative Importance Index (RII) and rank based on RII (high, medium, low) for the neighbourhood facilities. Among the 30, the 11 neighbourhood facilities which were ranked with "high" importance are shown in the shaded region of Table 6-5:

Table 6-5: Descriptive statistics of the importance of neighbourhood facilities according to the 50 respondents

Neighbourhood facilities	Min	Max	Mean	SD	RII	Level of importance
Supermarket	3	5	4.51	0.54	0.90	H
Pharmacy/medicine store	3	5	4.50	0.54	0.90	H
Grocery shops	3	5	4.48	0.58	0.90	H
Rickshaw/ auto-rickshaw stand	3	5	4.24	0.66	0.85	H
Mosque/Worship place	3	5	4.18	0.75	0.84	H
Playground	3	5	4.14	0.64	0.83	H
Doctor's chamber	3	5	4.00	0.70	0.80	H
Municipal waste collection points	3	5	3.88	0.49	0.78	H
Technician services (electrical, plumber, AC, freezer)	1	5	3.88	0.94	0.78	H
Park	1	5	3.80	0.86	0.76	H
Laundry shop	3	5	3.78	0.55	0.76	H
Hairdresser	2	5	3.54	0.61	0.71	M
Photocopy/mobile/land phone/fax service	2	5	3.52	0.65	0.70	M
Beauty parlour	2	5	3.50	0.61	0.70	M
Computer based service	2	4	3.46	0.61	0.69	M
Tailoring	1	5	3.46	0.73	0.69	M
Community police/barrack	2	5	3.46	0.97	0.69	M
Cyber café/internet service provider	2	4	3.44	0.61	0.69	M
Restaurant, tea bar, fast-food	2	5	3.43	0.76	0.69	M
Vehicle repair services	2	4	3.18	0.80	0.64	M
Recreational facilities and community halls	1	4	2.92	0.80	0.58	M
Fruit shop	1	5	2.92	1.03	0.58	M
Community club including indoor games for male and female	1	4	2.76	0.83	0.55	M
High school	1	4	2.56	0.81	0.51	L
Primary school	1	4	2.56	0.84	0.51	L
Cultural facilities	1	5	2.48	0.76	0.50	L
Sweet shop	1	4	2.40	0.83	0.48	L
Post office/courier services	1	4	2.34	0.87	0.47	L
Flower shop	1	4	2.14	0.73	0.43	L
Library	1	4	2.04	0.70	0.41	L

The neighbourhoods around the five case study buildings that housed the respondents of the second questionnaire survey were surveyed during the first field survey to study the 30 neighbourhood facilities recommended by DAP (Detailed Area Plan) for Dhaka. Figure 6-4 shows a typical neighbourhood survey, in an area, approximately 20 hectares (indicated by the circle in Figure 6-4), from the centre of the case study building (the shaded region in orange in Figures 6-4) to identify the number of each of the recommended 30 neighbourhood facilities.

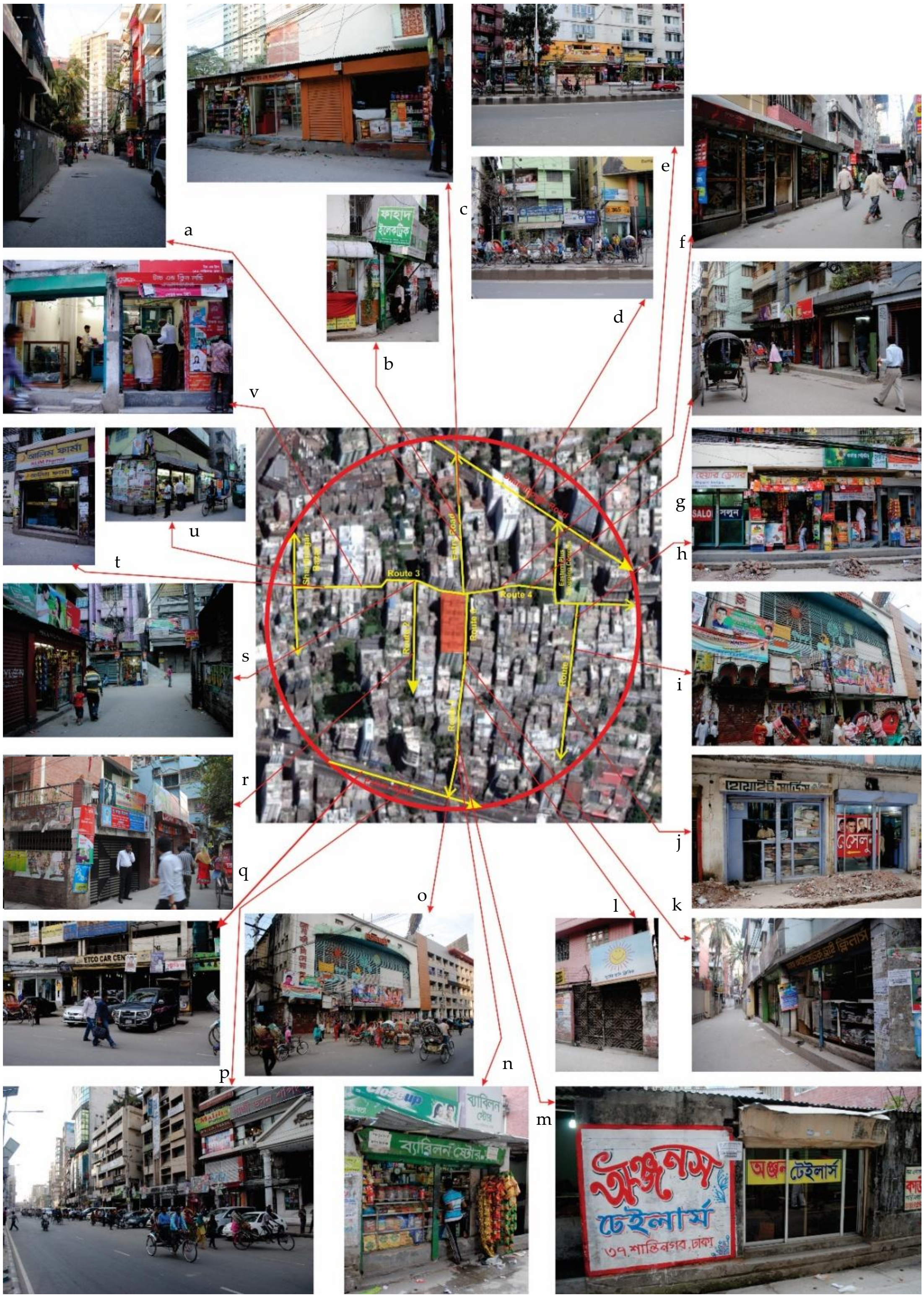


Figure 6-4: Neighbourhood facilities of one of the case study buildings (shaded in orange)

a= grocery; b=technician services; c=grocery; d= pharmacy; e= restaurant, bank, dentist's chamber; f=grocery, laundry shop; g= grocery, technician services; h=hair dresser, grocery, photocopy/mobile phone/fax shop; i=recreational facility (movie theatre); j=hair dresser, laundry shop; k= laundry shop; l= clinic; m=tailor shop; n=grocery; o= ;p=supermarket; q= vehicle repair service; r=grocery ; s= grocery; t= pharmacy; u= hair dresser, pharmacy; v= tailor, laundry shop;

The average number of each of the 30 neighbourhood facilities in the neighbourhoods of the five case study buildings, together with DAP's recommended number (minimum and maximum), are presented in Table 6-6. The shaded region in Table 6-6 presents the neighbourhood facilities that were ranked "high" importance by the respondents. The mean for the neighbourhood facilities in the five case study buildings shown in Table 6-6 demonstrates that there are some that were not present in these neighbourhoods even though they were ranked "high" importance by the respondents. These facilities include playgrounds, municipal waste collection points and parks. On the contrary, some neighbourhood facilities such as supermarkets, pharmacies, grocery shops, mosques, doctor's chambers and laundry shops in the neighbourhoods of the five case study buildings met both minimum and maximum planning guidelines of DAP. However, neighbourhood facilities such as rickshaw/auto-rickshaw stand and technician services fell short of the recommended minimum number.

Table 6-6: Neighbourhood facilities of the case study buildings and DAP's requirements

Neighbourhood facilities	**Case study (mean)**	**Planning guidelines (min)**	**Planning guidelines (max)**
Supermarket	2	1	2
Pharmacy	10	2	3
Grocery shops	16	7	10
Rickshaw/ auto-rickshaw stand	1	2	4
Mosque/Worship place	3	2	3
Playground	0	2	3
Doctor's chamber	6	2	3
Municipal waste collection points	0	1	1
Technician services	1	2	4
Park	0	1	2
Laundry shop	9	2	3
Hair dresser	3	2	3
Photocopy/mobile/land phone/fax service	7	2	2
Beauty parlour	3	1	2
Computer based service	8	1	1
Tailoring	9	1	2
Community police/barrack	0	2	2
Cyber café/internet service provider	4	1	2
Restaurant, tea bar, fast-food	13	2	4
Vehicle repair services	5	1	2
Recreational facilities and community halls	0	1	2
Fruit shop	3	2	3
Community club including indoor games	0	2	2

Neighbourhood facilities	Case study (mean)	Planning guidelines (min)	Planning guidelines (max)
High school	1	1	2
Primary school	1	2	3
Cultural facilities	0	1	2
Sweet shop	1	2	3
Post office/courier services	1	1	2
Flower shop	0	2	2
Library	0	1	2

6.3.2.6 Maintenance issues

The respondents were asked about the maintenance of the following eight building services: elevator, staircase, electrical services, plumbing, sewage, water drainage, fire-fighting facility and cleanliness of common spaces. The responses of the respondents for the maintenance of building services were based on a five point Likert scale, where "1" indicated "poor" and "5 "indicated "excellent". Table 6-7 presents the descriptive statistics together with the Relative Importance Index (RII) and maintenance level based on RII (high, medium, low) for these maintenance issues. Among the eight building services, elevators and fire-fighting facilities ranked "low" level of maintenance compared to the other building services as shown in Table 6-7. None of the building services received a "high" rank for their maintenance.

Table 6-7: Descriptive statistics for maintenance of building services in 117 apartments

Building services	Min	Max	Mean	SD	RII	Maintenance level
Sewage	1	5	3.45	0.79	0.69	M
Water drainage	1	5	3.39	0.85	0.68	M
Electrical services	2	5	3.31	0.81	0.66	M
Plumbing	1	5	3.14	0.71	0.63	M
Staircase	2	5	3.09	0.74	0.62	M
Cleanliness of common space (lobby, staircase, corridor, waste collection spot)	2	5	3.08	0.74	0.62	M
Elevator	1	5	2.70	0.98	0.54	L
Fire-fighting facilities	1	3	2.20	0.75	0.44	L

The respondents were also asked if inspections were carried out regularly to ensure the smooth operation of building services. The responses of the respondents for this question were a yes and no scale, where "0" indicated "no" and "1" indicated "yes". Descriptive statistics of the results show that the mean value of regular inspections of the building services was 0.07 (SD= 0.25), indicating that regular inspections are carried out in only 7% of the apartments surveyed.

The respondents were asked about the frequency of regular inspections on the following services: electrical installations, water connections, gas connections, drainage systems, elevators and fire-safety services. The responses of respondents for the frequency of these regular inspections were based on a five point Likert scale, where "1" indicated "never" and "5" indicated "every three months". Table 6-8 presents the descriptive statistics together with the Relative Importance Index (RII) and level of regular inspections based on RII (high, medium, low) for the regular inspections of building services. It is evident from the RII in Table 6-8 that periodical regular inspections were not carried out in the buildings.

Table 6-8: Descriptive statistics for regular inspections of building services in the 117 apartments

	Min	Max	Mean	SD	RII	Level of regular inspections
Elevator	1	5	1.81	0.95	0.36	L
Fire services	1	5	1.79	0.95	0.36	L
Water connections	1	5	1.41	0.67	0.28	L
Drainage systems	1	5	1.38	0.70	0.28	L
Electrical installations	1	5	1.34	0.61	0.27	L
Gas connections	1	5	1.32	0.50	0.26	L

6.3.2.7 Awareness and education

Figure 6-5 shows the observation of public awareness programs by the respondents. Compared to awareness programs on water and gas conservation and household waste management, more respondents (about 28%) have heard of electricity conservation.

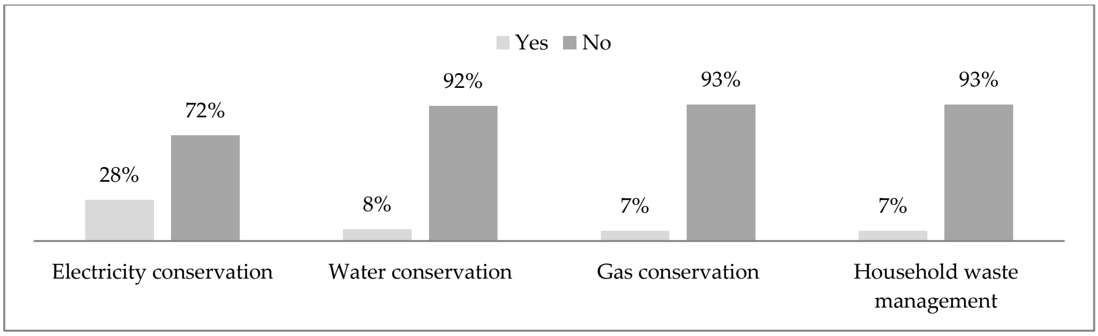


Figure 6-5: Observation of public awareness programs according to the 117 respondents

The respondents (if they were the owners of the apartments) were asked to rank the level of interaction with the architect and developer during the design and construction phases of their apartment. The responses of the respondents were based on a six point Likert scale, where “1” indicated “poor” and “5” indicated “excellent”. Descriptive statistics of the results (the owners of the apartments) show that the mean value of the level of interaction with the architect and developer is 2.57 (SD=1.11), which means that the level of interaction lies between “somewhat good” and “moderately good”.

6.3.3 Spatial Design Issues

6.3.3.1 Physical characteristics of the 30 high-rise residential buildings

Descriptive data on the physical characteristics of the high-rise residential buildings surveyed are presented in Table 6-9. The 30 high-rise residential buildings surveyed had a minimum of 7 floors and a maximum of 20 floors. The mean height of the buildings was 15 floors, and there were 6 apartments per floor on average, with the buildings on average having two elevators. The 117 apartments surveyed in the 30 buildings varied in size from 84 square metres to 265 square metres. The mean size of the apartments surveyed was 135 square metres. Among the apartments surveyed, 8 apartments had two bedrooms, 98 apartments had three bedrooms and 10 apartments had four bedrooms. The mean number of bedrooms was 3, as shown in Table 6-9. In this study bedroom 1 refers to the master bedroom, which is always bigger in size compared to the other bedrooms. Most of the buildings surveyed had community and prayer halls and about 40% of the buildings were mixed use developments. The respondents were asked if the parking facility was sufficient for them. 69% of respondents remarked that the parking facility was sufficient, while 3% pronounced the parking facility to be insufficient. The remaining 28% of the respondents did not own a motor vehicle. In response to the question on the overall condition of the building, the mean for the overall condition of the building was 3.20. The responses of the respondents were based on a five point Likert scale, where “1” indicated “poor” and “5” indicated “excellent”.The observations seen here are typical of general practice. Typical floor plans of high-rise residential buildings in Dhaka are included in Appendices E1-E9.

Table 6-9: Physical characteristics of the 117 apartments

	Min	Max	Mean	SD
Total number of floors	7	20	15	3.76
Total number of apartments per floor	2	20	6	2.26
Number of elevators	1	4	2	1.06
Apartment size (square metres)	84	265	135	356.96
Number of bedrooms per apartment	2	4	3	0.40
Number of living rooms per apartment	1	2	1	0.24
Number of dining rooms per apartment	1	1	1	0.09
Number of kitchen per apartment	1	1	1	0.00
Number of balconies per apartment	1	5	2	0.88
Number of bathrooms per apartment	1	5	3	0.70
Number of servant's room per apartment	0	1	0.22	0.41
Number of servant's toilets per apartment	0	1	0.53	0.50
Number of storage rooms per apartment	0	2	0.18	0.40

6.3.3.2 Design characteristics of the five case study buildings

During the first field survey of the 50 apartments in the five case study buildings, all the 50 apartments surveyed had three bedrooms and the mean household size in the 50 apartments surveyed was 4.6. Table 6-10 shows a summary of the descriptive statistics for the design characteristics of the 50 apartments.

Table 6-10: Descriptive statistics of design characteristics of the 50 apartments

	Min	Max	Mean	SD
Apartment size	88.26 m^2	203.64 m^2	133.17 m^2	30.04
Floor level	2.00	20.00	11.00	4.54
Size of bedroom 1	10.31 m^2	20.81 m^2	12.97 m^2	2.89
Size of bedroom 2	9.29 m^2	13.77 m^2	10.19 m^2	2.43
Size of bedroom 3	9.01 m^2	14.27 m^2	10.99 m^2	1.24
Size of living room	9.75 m^2	16.38 m^2	11.82 m^2	4.24
Size of dining room	10.73 m^2	27.48 m^2	16.78 m^2	5.25
Size of kitchen	4.92 m^2	14.01 m^2	7.33 m^2	2.28
Total window area	11.66 m^2	27.51 m^2	20.12 m^2	6.18
Total shading depth	0.05 m	1.08m	0.51 m	0.21
Effective canyon ratio	0.13	11.92	3.91	2.95

Table 6-11 shows the distribution (in percentage) of windows across the various rooms of the 50 apartments surveyed. About 98% of the apartments surveyed had two windows in bedroom 1 (master bedroom). Bedroom 3 is given less priority in terms of the number of windows as compared to bedroom 2. It is interesting to note that about 20% of the apartments surveyed did not have any window in living rooms, while 10% did not have any window in kitchens.

Table 6-11: Distribution of windows in various rooms of the 50 apartments

Apartments	Percentage (%)
Two windows in bedroom 1	98
Two windows in bedroom 2	42
Two windows in bedroom 3	32
Two windows in living rooms	34
One window in living rooms	46
No windows in living rooms	20
One window in dining rooms	90
One window in kitchens	72

Table 6-12 shows the descriptive statistics for the window areas in various rooms of the 50 apartments. The total mean window areas in bedroom 1, bedroom 2, bedroom 3 and living room are 4.98, 2.96, 2.68, 4.40 square metres respectively.

Table 6-12: Descriptive statistics for the window areas (in square metres) of the 50 apartments

	Min	Max	Mean	SD
Window 1 area of bedroom 1	0.00	4.20	2.61	0.79
Window 2 area of bedroom 1	0.84	5.94	2.37	0.86
Window 1 area of bedroom 2	1.00	3.60	2.20	0.58
Window 2 area of bedroom 2	0.00	3.00	0.76	0.96
Window 1 area of bedroom 3	0.00	3.10	2.06	0.44
Window 2 area of bedroom 3	0.00	2.50	0.62	0.92
Window 1 area of living room	0.00	9.00	3.44	2.98
Window 2 area of living room	0.00	3.10	0.96	1.37
Window 1 area of dining room	0.00	7.50	4.45	2.63
Window 1 area of kitchen	0.00	2.10	1.07	0.77

The effective canyon ratio was calculated for each external wall on the relevant floor level by taking into account the height of the top of the building directly opposite of an external wall, from that floor and the gap between the two buildings as depicted in Figure 6-6. The building height of the adjacent residential buildings around the 5 case study buildings varied from 6 floors to 20 floors while the gaps between buildings varied from 1.4 metres to 6 metres.

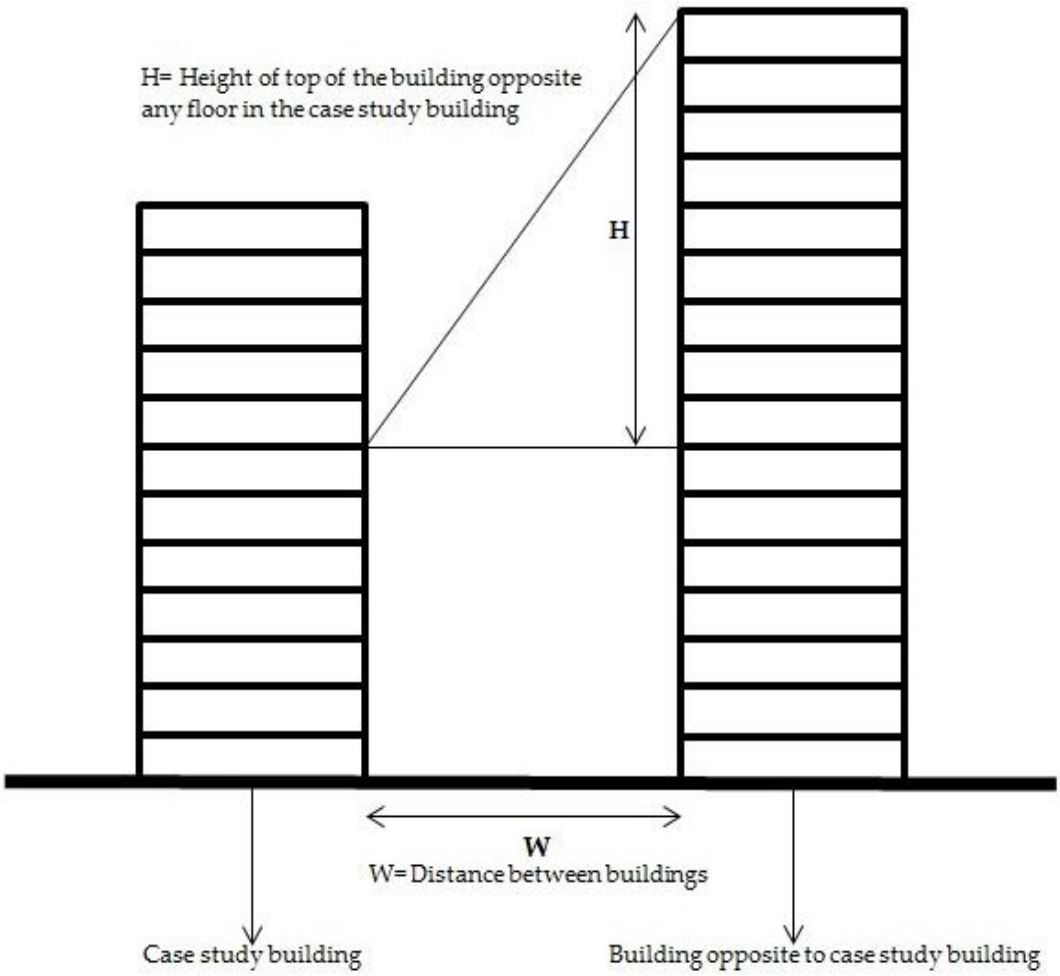


Figure 6-6: Cross section of a case study building and the neighbourhood to illustrate effective canyon ratio

The respondents were asked if the parking facility was sufficient for them. About 69% of respondents remarked that the parking facility was sufficient, while 3% pronounced the parking facility to be insufficient. The remaining 28% of the respondents did not own a motor vehicle.

6.3.3.3 Social interaction

6.3.3.3.1 Interaction with neighbours

The respondents were asked to rank the importance of interaction (such as greetings) with neighbours in the different apartments of their building. The responses of the respondents were based on a five point Likert scale, where “1” indicated “not important” and “5” indicated “extremely important”. Descriptive statistics of the results showed that the mean value of the importance of interaction with neighbours was 3.74, which means that the importance lies between "moderately important" and "very important". The respondents were asked to name the place(s) where they interact with their neighbours in an open-ended question. It must be noted that as this question was open-ended, the most frequent responses were coded and the responses have been presented using frequency distributions in Figure 6-7. Figure 6-7 shows that the majority of the respondents (61) interacted with neighbours in elevators; 11 respondents interacted in corridors; 5 in mosques; 4 did not interact; and 13 respondents said that there was no proper place for interaction. These findings are also similar to that of Housing and Development Board (2000) cited in Yuen (2011), where corridors and lift lobbies were also the common places of interaction among the residents of high-rise residential buildings in Singapore.

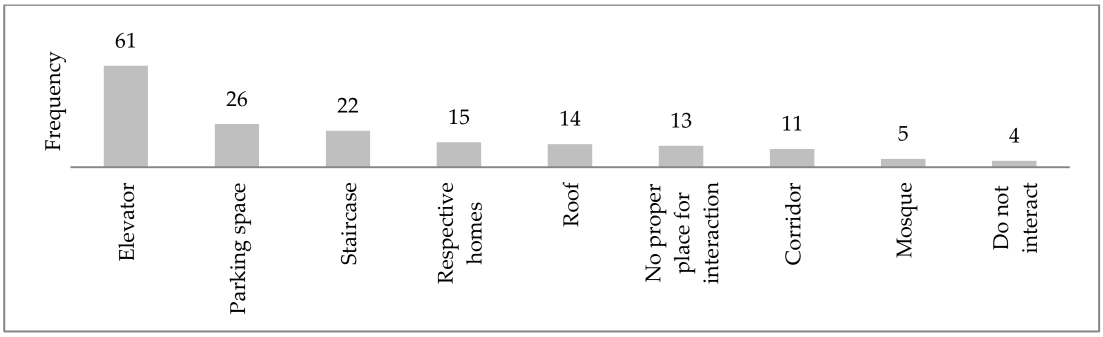


Figure 6-7: Places of interaction with neighbours according to the 117 respondents

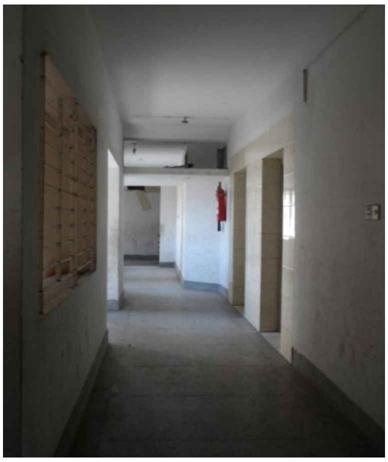
This also confirms the study of Islam (2007) and Razzaque and Nahid (2007) suggesting that a vertical circulation lobby (elevator and stair) acts as a key interaction space of households and their neighbours who share the same floor. It can thus be concluded most of the occupants interact with each other while travelling in elevators, walking up or down the stairs and walking towards their apartment in corridors. Islam (2007) defined the shared spaces of movement from the car drop off place to the elevator lobby, and finally to the space in front of the main entrance of the apartments as "spaces for pauses" where the neighbours, service and apartment staff meet and interact with each other. Islam (2007) also asserts that these shared spaces for pauses must have the multiplicity that the neighbourhood streets once had, for instance, watching movements of people in the city, gardening corners and outdoor furniture for promoting social interaction. Furthermore, according to Mowla (1999), traditionally, social interaction in Bangladesh is outdoor based, but open space is rarely found in high-rise residential buildings in Dhaka (Razzaque & Nahid 2007). Razzaque and Nahid (2007) also assert that left over space in front of a building does not function as well as a well-designed, open to nature community space.

A cross tabulation of staircases as a place of interaction with neighbours and the number of apartments per floor showed a significant difference (p=0.00). Similarly, a cross tabulation of elevator lobbies as a place of interaction with neighbours and the number of apartments per floor showed a significant difference (p=0.03). The lesser the number of apartments per floor the more interaction was observed in staircases and elevator lobbies. When there were more apartments per floor, the building floor plan was more elongated and the apartments did not face each other, compared to the compact shape of the building floor plan where there were fewer apartments facing each other per floor. When the building floor plans were elongated, the staircase and elevator lobby tend to be dispersed, and did not receive daylight and natural ventilation. On the contrary, when the building floor plan was compact, the lobby and the corridor were central and received sufficient daylight and natural ventilation. Figure 6-8a is a photograph taken in the corridor of a building that had four apartments per floor (refer to floor plan E-4 in Appendix E), and Figure 6-8b is a photograph taken in the corridor of a building that had six apartments per floor (refer to floor plan E-7 in Appendix E). The occupants of both these buildings interacted in the corridor, staircase and elevator lobby.

(a) (b)

Figure 6-8: Corridors in buildings with 4 and 6 apartments per floor

Figure 6-9a is a photograph taken in the corridor of a building that had 11 apartments per floor (refer to floor plan E-8 in Appendix E) and Figure 6-9b on is a photograph taken in the corridor of a building that had 20 apartments per floor (refer to floor plan E-9 in Appendix E). None of the occupants of these two buildings was observed to be interacting in the staircase or in the elevator lobby.



(a) (b)

Figure 6-9: Corridors in buildings with 11 and 20 apartments per floor

6.3.3.3.2 Playing space for children

The respondents were asked to name the place(s) where their children play in an open-ended question. Figure 6-10 shows that the majority, about 48 respondents, reported that their children played in their homes; 38 said that their children played in parking spaces; while only 5 respondents' children played in the nearby playgrounds and only 4 respondents' children played in the nearby parks. Only 2 respondents' children played in the designated play area on the ground floor. Roof space was also observed as a playing space for children among 17 respondents.

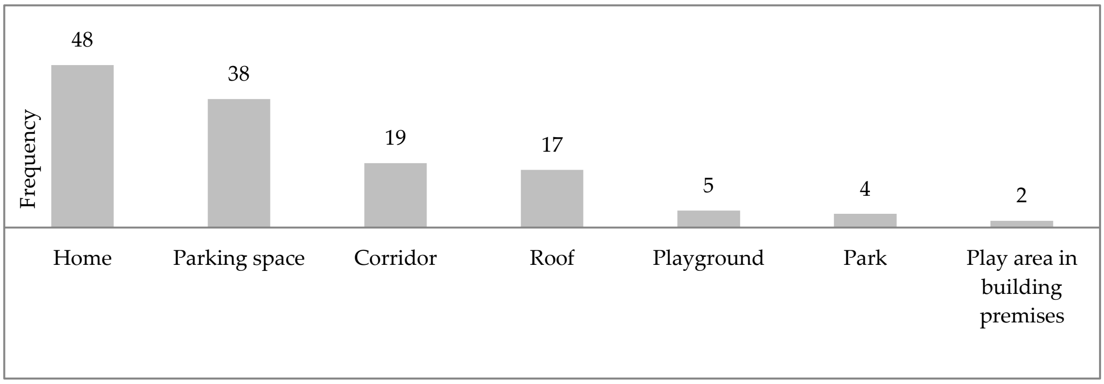
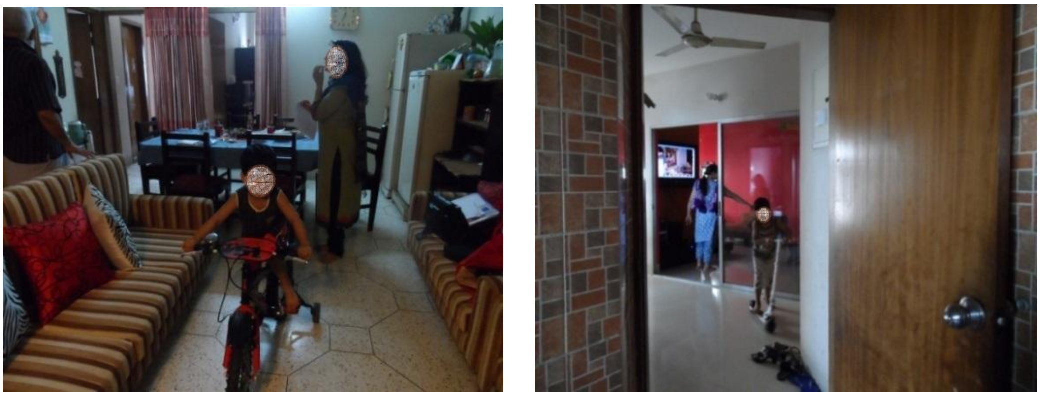


Figure 6-10: Playing spaces for children according to the 117 respondents

Figures 6-11 and 6-12 are photographs of children playing in the corridors and inside the apartments respectively, while Figure 6-13 shows the designated playing space for the children of a high-rise residential complex of four 16 storied buildings with 171 apartments. Figure 6-14 also shows the only playing area for the children of a high-rise residential complex of twenty-seven 16 storied buildings with 1803 flats. If each apartment had at least one child in the high-rise residential complex of Figure 6-13, there would be 171 children and likewise, there would be 1803 children in the high-rise residential complex of Figure 6-14. The playing space in Figure 6-14 was not designated as a playing space for children; in fact, it was the circulation area inside the high-rise residential complex.

(a) (b) (c)

Figure 6-11: Children playing in the corridors



(a) (b)

Figure 6-12: Children playing inside the apartments

Figure 6-13: Designated playing space for of a high-rise residential complex of 4 buildings

Figure 6-14: Playing space for the children of a high-rise residential complex of 27 buildings

6.3.3.4 Open space

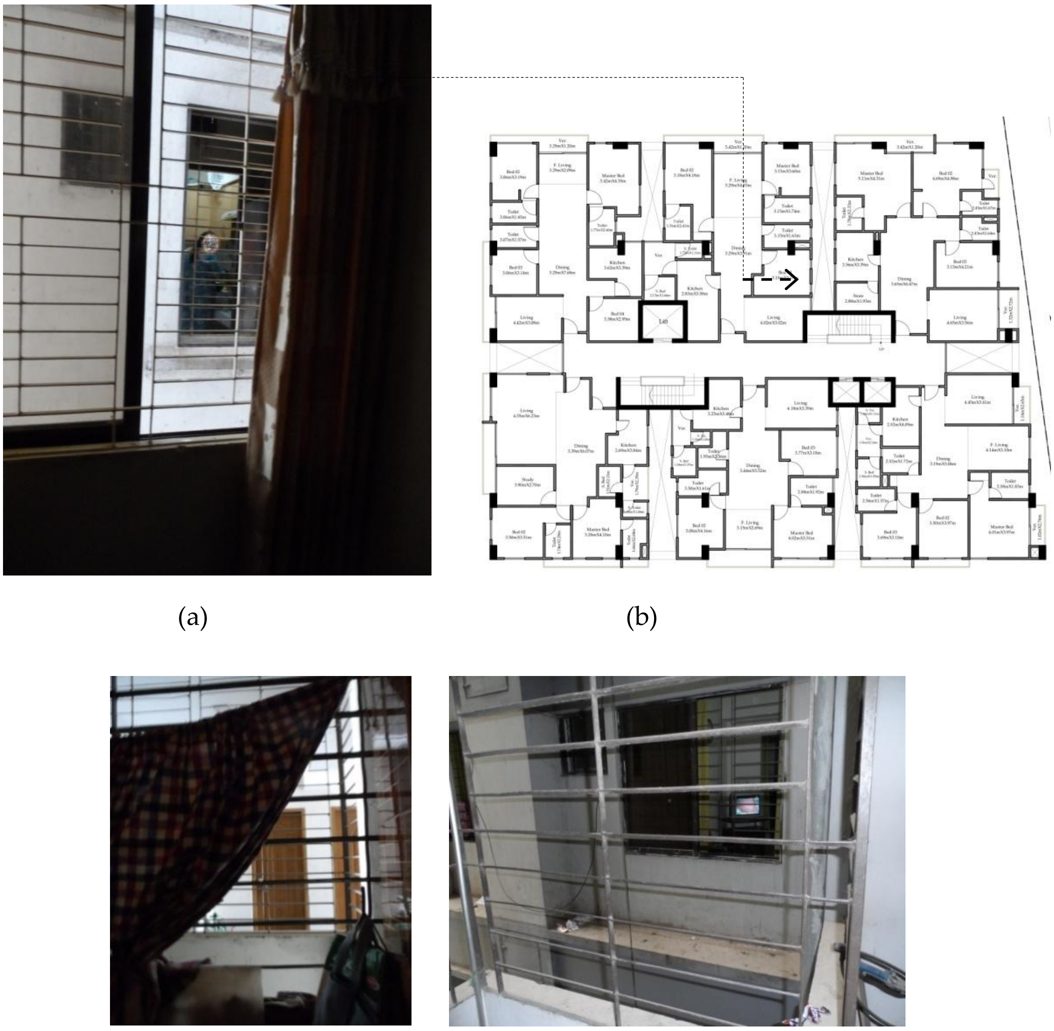
According to 74% of the respondents, the buildings occupied the whole land area without leaving any designated open space. A physical survey of five buildings, as shown later in Section 6.3.5.2.2 of this chapter, found that the mean of open space percentage (of the total site) in those buildings was 26%.

About 92% of the respondents answered that they wanted more open space when asked. The respondents were asked if there was any green space in any of the following places: ground floor, roof, and balcony. The majority, about 60 respondents, said that there was no garden/green space in any of the above mentioned places. About 23 respondents reported some greenery on the ground floors, 20 on the balconies and 9 on the roofs.

6.3.3.5 Visual privacy

The respondents were asked to rank visual privacy from the exterior in principal areas of the apartment. The responses of the respondents were based on a five point Likert scale, where 1 indicates "not private" and 5 indicated "extremely private". Descriptive statistics of the results showed that the mean value of the visual privacy was 2.87, which means that the visual privacy lied between "somewhat private" and "moderately private".

Curtains were found in all almost all rooms of the apartments to act as a screen for visual privacy across adjacent apartments or buildings. Figure 6-15a is a photograph taken from the living room of one apartment of a building with six apartments per floor (when the curtains were withdrawn), where an occupant of a neighbouring apartment in the same building could be seen. The arrow in Figure 6-15b is the floor plan of the apartment in a building with six apartments in each floor, from which the photograph in Figure 6-15a was taken. The distance between the apartments was 1.6 metres. The photograph in Figure 6-15c shows curtains used for visual privacy even on the balcony of an apartment, while the photograph in Figure 6-145d shows the living room of an apartment in a neighbouring building.



(a) (b)

(c) (d)

Figure 6-15: Lack of visual privacy in the apartments

6.3.3.6 Inclusiveness of opportunity

The respondents were asked whether the buildings had ramps, handrails in toilets and bathrooms and other necessary design features for the elderly and people with a disability; and whether the elevators in the buildings were large enough to fit in a wheelchair and stretcher. The responses to both questions were based on a yes and no scale, where “0” indicated “no” and “1” indicated “yes”. The results in Table 6-13 showed that none of the buildings had ramps, handrails in toilets and bathrooms and other necessary design features for the elderly and people with a disability. Only a small fraction of the respondents said that elevators in the buildings were large enough to fit a wheelchair and stretcher as evident from the mean in Table 6-13.

Table 6-13: Descriptive statistics for design features for the elderly and disabled in 117 apartments

	No	Yes	Mean	SD
Presence of ramps, hand rails in toilets and bathrooms and other necessary design features for the elderly and people with disability	0	0	0.00	0.00
Presence of elevators large enough to fit a stretcher	0	1	0.02	0.13

6.3.4 Environmental Issues

6.3.4.1 Day-lighting and natural ventilation

The respondents were asked to rank the overall day-lighting conditions and natural ventilation in their rooms respectively as shown in Table 6-14. The responses of the respondents for overall day-lighting in the apartments were based on a five point Likert scale, where “1” indicated “poor” and “5” indicated “excellent”. The responses of the respondents for natural ventilation in the rooms were based on a five point Likert scale, where “1” indicated “very rarely” and “5” indicated “very often”. Descriptive statistics of the results showed that the mean value of the overall day-lighting conditions in the apartments was 3.15, which means that the day-lighting conditions varied between “moderately good” and “very good”, while the mean value of the natural ventilation in the rooms was 3.38, which means that the natural ventilation varied between “occasionally” and “often”. Data on daylight in the various rooms of the apartments are discussed more elaborately in Section 6.3.5.3.1

Table 6-14: Descriptive statistics for perceived day-lighting and natural ventilation in 117 apartments

	Min	Max	Mean	SD
Day-lighting	1.00	5.00	3.15	0.96
Natural ventilation	1.00	5.00	3.38	0.97

6.3.4.2 Fire safety

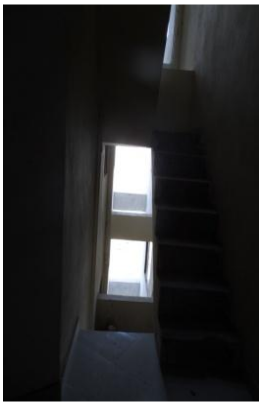
The respondents were asked to rank the overall condition of fire safety in the buddings. The responses of the respondents were based on a five point Likert scale, where “1” indicated “poor” and “5” indicated “excellent”. Descriptive statistics of the results showed that the mean value of the overall fire safety in the buildings was 2.20 (SD= 0.75) which means that fire safety varied between “somewhat good” and “moderately good”. The respondents were also asked if the buildings had the following fire-safety provisions: enclosed fire stairs, fire exit, smoke detector, fire alarms, fire extinguishers, sprinklers, water hydrant, evacuation layout plan, clear signage indicating exit routes, regular fire drills and fire wardens and the responses are presented in Table 6-15. The severity of the problems regarding fire safety in the buildings surveyed can be highlighted by observing the frequency of the existing fire-safety provisions in the buildings as shown in Table 6-15.

Table 6-15: Frequency of fire safety provisions in 30 buildings

Fire safety features	Frequency
Fire extinguishers	27
Fire alarms	12
Water hose pipe	11
Enclosed fire stairs	4
Fire drills	3
Clear signage indicating exit routes	2
Fire exit	2
Smoke detector	1
Water hydrant	1
External stair	1
Sprinklers	0
Evacuation layout plan	0
Fire warden	0

Only four out of the 30 buildings surveyed had enclosed fire stairs, a very basic requirement. Even though fire extinguishers were present in 27 buildings, a physical survey of the apartments showed that the fire extinguishers in some had already expired when it was conducted in 2013 (Figure 6-16a). The enclosed fire stairway shown in Figure 6-16b is too narrow and does not conform to standards laid out in the Bangladesh National Building Code (BNBC).

(a) Expired fire extinguisher



(b) Narrow enclosed fire stair

Figure 6-16: State of fire safety provisions

6.3.4.3 Pollution

The respondents were asked about the following three environmental pollutions in the buildings: water, air and sound pollution. The responses of the respondents for severity were based on a five point Likert scale, where "1" indicated "not a problem" and "5" indicated "severe". Among the three environmental pollutions, severity of sound pollution was highest (mean= 3.24), followed by water pollution and air pollution, as shown in Table 6-16.

Table 6-16: Descriptive statistics for pollution in the 117 apartments

Pollution	Min	Max	Mean	SD
Air pollution	1	5	2.20	0.95
Water pollution	1	5	2.45	0.73
Sound pollution	1	4	3.24	0.81

The respondents were asked to rank the perceived noise in their apartments. The responses of respondents to the perceived noise in their apartments were based on a five point Likert scale, where "1" indicated "extremely noisy" and "5" indicated "not noisy". Descriptive statistics of the results showed that the mean value of the perceived noise in the apartments was 1.76 (SD=0.81), which means that the noise varied between "moderately noisy" and "somewhat noisy", irrespective of the floor.

6.3.4.4 Household waste management

The respondents were asked about management of household waste. The responses of the respondents for the management of household waste were based on a five point Likert scale, where "1" indicated "poor" and "5" indicated "excellent". Descriptive statistics of the results showed that the mean value of the management of household waste in the apartments was 3.31 (SD= 1.24), which means that the management of household waste varied from "moderately good" to "very good".

About 97% of the buildings surveyed did not have the provision for common waste collection in the building complex, and none of the apartments collected waste separately so that they could be recycled.

About 37% of the respondents had heard of waste separation in three bins (organic, recyclable and non-recyclable). Even though in one building three different types of waste bins were provided by the building authority for separate collection of waste, these waste bins were either unused or used for different purposes other than that they were assigned for as shown in Figure 6-17.

(a) clothes stored in bin

(b) paper & plastic in organic bin

Figure 6-17: Different use of bins in apartments of one building

Household waste is managed in the high-rise residential buildings in the following three ways as shown in Figure 6-18.

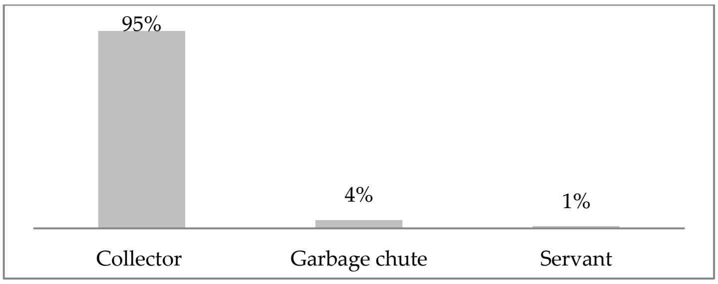


Figure 6-18: Waste collection systems from the 117 apartments

- Collector(s) employed by the building authority collected waste from door-to-door in a large bucket as shown in Figures 6-19 a, b and c. The waste was then transferred to a non-motorised vehicle (Figures 6-19d), driven off and dumped at the nearest "waste dumping spot" by the collector/s (Figure 6-19e).



(a) (b) (c)


(d) (e)

Figure 6-19: Collection and disposal of waste

- Waste was first disposed of from the apartments through garbage chutes (Figures 6-20a and 6-20b). The waste was then transferred from the garbage chutes by collectors employed by the building authority to non-motorised vehicles (Figure 6-20c) and driven off to the nearest "waste dumping spot" by these collector(s).

(a) (b) (c)

Figure 6-20: Waste collection in garbage chute

- The respondents in the apartments (usually servants) disposed the waste (collected in buckets) to drums (Figure 6-21) that were placed in the building complex. Household waste from these drums were collected in a non-motorised vehicle by community based waste collectors and dumped to the nearest "waste dumping spot".

Figure 6-21: Maidservant dumping waste in the drum located in the building complex

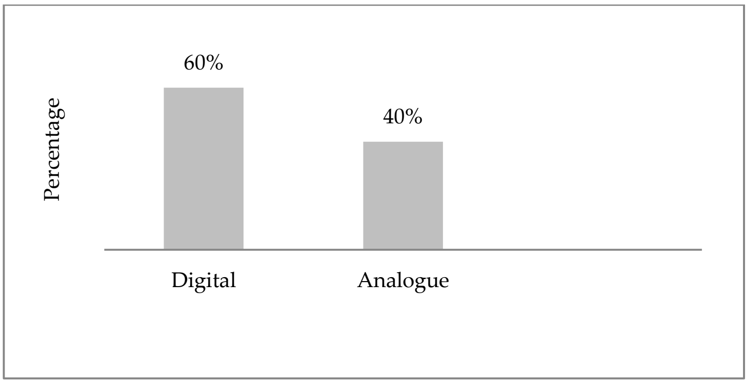
6.3.4.5 Resource management

The respondents were asked about the shortage of electricity, water and gas in the buildings. The responses of the respondents for severity were based on a five point Likert scale, where “1” indicated “not a problem” and “5” indicated “severe”. Among the three resources, electricity, gas and water, shortage of electricity was the most notable, followed by shortage of gas and electricity as shown in Table 6-17.

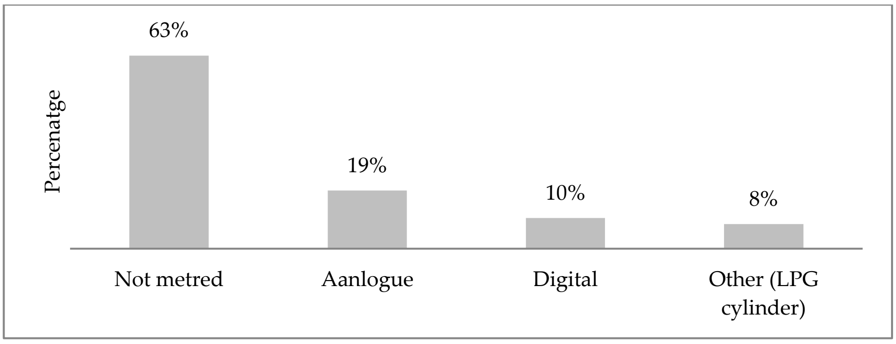
Table 6-17: Descriptive statistics for supply of resources in the 117 apartments

Resources	Min	Max	Mean	SD	RII
Water supply	1	3	3.37	0.65	0.67
Gas supply	1	4	3.48	0.67	0.70
Electricity supply	1	2	3.87	0.34	0.77

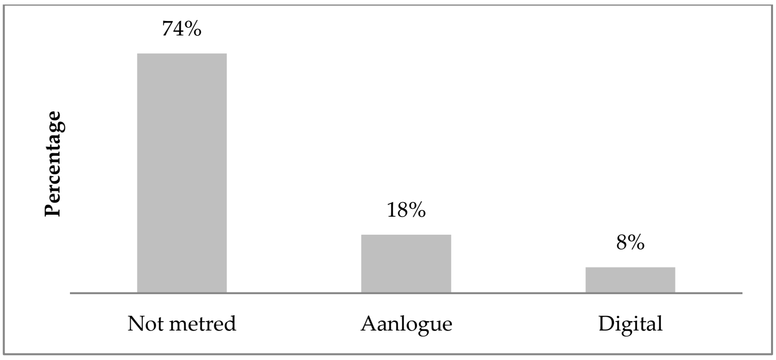
The respondents were asked about the metering systems of electricity, gas and water used in the apartments. Figure 6-22 show the different types of metering systems employed in the buildings for electricity, water and gas usage. About 63% and 74% of the apartments did not have any metering systems for gas and water usage respectively, as shown in Figures 6-22b and 6-22c.



(a) Metering systems for electricity usage



(b) Metering systems for gas usage



(c) Metering systems for water usage

Figure 6-22: Resource metering systems in the 117 apartments

The respondents were asked about the awareness of water saving techniques and the presence of water-saving devices in the apartments respectively. About 63% of the respondents reported not being aware of water saving techniques. Table 6-18 shows the frequency of different water saving devices in the apartments. None of the buildings had the provision for collecting and reusing rainwater.

Table 6-18: Water saving devices used in the 117 apartments

Water saving devices used by respondents	Frequency
Water saving taps	1
Water saving flushes	8

6.3.5 The satisfaction of high-rise living

In the second household questionnaire survey of the 50 apartments (with three bedrooms) in the five case study buildings, the respondents were asked about their overall satisfaction with high-rise living. The responses of the respondents were based on a five point Likert scale, where "1" indicated "not satisfied" and "5" indicated "extremely satisfied". Descriptive statistics of the results showed that the mean value of satisfaction in living in the high-rise residential buildings was 3.42, indicating that satisfaction varied between "moderately satisfied" and "very satisfied".

Based on the literature review in Chapter 3, building attributes were identified that are likely to affect residential satisfaction in high-rise residential buildings. These building attributes were requested to be ranked by respondents in the third question of the second household questionnaire survey. All the responses to these building attributes, presented in the sections below, were based on a five point Likert scale, where "1" indicated "not satisfied" and "5" indicated "extremely satisfied". Three important levels of satisfaction of living in high-rise residential buildings: high (H) ($0.75 \leq$ RII≤ 1), medium (M) ($0.6 \leq$ RII≤ 0.75) and low (L) ($0 \leq$ RII≤ 0.6) were found based on the Relative Important Index (refer to Chapter 4). In interpreting the results, the building attributes with RII between 0.75 to 1 (H) are considered as having the most contribution to meeting respondents' needs and expectations and thus providing high levels of satisfaction. Building attributes with medium (M) ($0.6 \leq$ RII≤ 0.75) and low (L) ($0 \leq$ RII≤ 0.6) satisfaction levels are areas where attention is needed in order to improve respondents' satisfaction.

6.3.5.1 Social satisfaction

Social attributes which were likely to create an impact on the satisfaction of high-rise living included aspects such as community safety and security, availability of neighbourhood facilities and regular inspections of the following as part of the maintenance issues: fire safety and protection, elevator, electrical installations, plumbing systems, sewage systems, building exterior, building interior and structural components. Table 6-19 presents the descriptive statistics together with the Relative Importance Index (RII) and satisfaction level based on RII (high, medium, low) for the social aspects affecting residential satisfaction. The results showed that only community safety and security within the building had a "high" satisfaction level.

Table 6-19: Descriptive statistics for the social aspects affecting residential satisfaction in 50 apartments

	Min	**Max**	**Mean**	**SD**	**RII**	**Satisfaction level**
Community safety and security	2	5	3.78	0.74	0.76	H
Availability of neighbourhood facilities	1	3	3.06	0.89	0.61	M
Regular inspection of elevator	1	4	2.52	1.03	0.50	L
Regular inspection of fire safety and protection	1	4	1.90	0.84	0.38	L
Regular inspection of plumbing systems	1	3	1.76	0.72	0.35	L
Regular inspection of sewage systems	1	5	1.50	0.74	0.30	L
Regular inspection of building interior	1	2	1.48	0.50	0.30	L
Regular inspection of building exterior	1	2	1.46	0.50	0.29	L
Regular inspection of electrical installations	1	3	1.44	0.54	0.29	L
Regular inspection for structural problems	1	2	1.25	0.44	0.25	L

6.3.5.2 Spatial design issues

Spatial design attributes of the buildings which were likely to influence satisfaction of high-rise living included aspects such as aesthetic appearance, visual privacy, open space around the building, setback distance, space for interaction with neighbours, playing space for children, orientation of rooms, sizes of rooms (bedrooms, living room, dining room, kitchen, toilets), layout plans of rooms, interior design, efficiency of usable area, storage facilities, efficiency of community hall , efficiency of prayer space, design of kitchen and bathroom facilities, design features for the elderly and disabled and protection from heat gains (shading). Table 6-20 presents the descriptive statistics together with the Relative Importance Index

(RII) and satisfaction level based on RII (high, medium, low) for the spatial design features affecting residential satisfaction.

Table 6-20: Descriptive statistics for the spatial design aspects affecting residential satisfaction in 50 apartments

	Min	Max	Mean	SD	RII	Satisfaction level
Size of toilet	2	5	3.84	0.77	0.77	H
Size of kitchen	1	5	3.80	1.03	0.76	H
Aesthetic appearance of building	2	5	3.80	0.81	0.76	H
Room layout plan	3	5	3.78	0.65	0.76	H
Size of bedroom 1	2	5	3.76	0.85	0.75	H
Interior design	2	5	3.76	0.96	0.75	H
Orientation of rooms	2	5	3.76	0.85	0.75	H
Efficiency of usable area	3	5	3.76	0.62	0.75	H
Design of bathroom facilities	2	5	3.76	0.66	0.75	H
Design of kitchen facilities	2	5	3.76	0.69	0.75	H
Size of dining room	1	5	3.72	1.64	0.74	M
Efficiency of community space	1	5	3.34	1.00	0.67	M
Size of bedroom 2	1	5	3.34	1.22	0.67	M
Size of living room	1	5	3.34	1.55	0.67	M
Visual privacy	2	3	3.26	0.88	0.65	M
Size of bedroom 3	1	5	2.78	1.54	0.56	M
Open space around the building	1	5	2.72	0.86	0.54	L
Setback distance	1	5	2.72	1.64	0.54	L
Storage facilities	1	5	2.16	1.25	0.43	L
Space for interaction with neighbours	1	3	2.08	0.75	0.42	L
Playing space for children	1	3	1.96	0.88	0.39	L
Design features for the elderly and disabled	1	3	1.32	0.59	0.26	L

Among the different spatial design aspects, size of toilet, efficiency of prayer space, size of kitchen, aesthetic appearance of the building, room layout plan, size of bedroom 1, interior design, orientation of rooms, efficiency of usable area and design of bathroom and kitchen facilities were the only design aspects that had a relative importance index (RII) of 0.75, signifying "high" satisfaction as shown in the shaded regions of Table 6-20. All other spatial design aspects either had "medium" or "low" levels of satisfaction and thus, these spatial design aspects require improvements for increasing the satisfaction level of the respondents. As most of the spatial design aspects were scored "medium" to "low", the spatial design aspects that can be analysed further have been presented in the following sections.

6.3.5.2.1 Visual privacy

Figure 6-23 shows a photograph in which the activities in the apartment directly opposite to the surveyed apartment could be seen quite clearly, signifying the lack of visual privacy. The setback distance between the apartments in Figure 6-23 is 1.5 metres.

Figure 6-23: Low setback distance between buildings causing lack of visual privacy

In order to study the effect of setback distance on visual privacy, the setback distances around all sides of 50 high-rise residential buildings were first measured during the first field study. The mean setback distance between the buildings was 5.6 metres, minimum setback distance was 1.4 metres, while maximum setback distance was 19.3 metres (SD= 4.54). The distance between the buildings in Figure 6-24 is 2 metres.

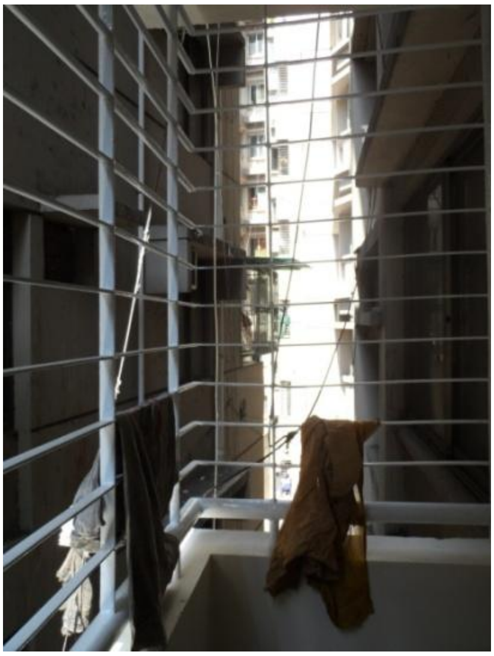


Figure 6-24: Low setback distance between buildings

Next, a one-way between-groups analysis of variance (ANOVA) was conducted in SPSS to explore the impact of setback distance (in metres) between the buildings on levels of respondents' satisfaction of visual privacy. The levels of satisfaction of visual privacy were divided into five groups (Group 1: not satisfied; Group 2: somewhat satisfied; Group 3: moderately satisfied; Group 4: very satisfied; Group 5: extremely satisfied). The results of Table 6-21show that there was a significant difference at the $p < 0.05$ level for the setback distance between the buildings and the five groups of visual privacy. If the mean setback distance between the buildings was 7.3 metres, respondents were "very satisfied" about visual privacy, while a mean setback distance of 9.4 metres resulted in the respondents being "extremely satisfied".

Table 6-21: ANOVA for setback distance and respondents' satisfaction of visual privacy

Analysis	**Findings**	**Satisfaction level**	**Mean setback distance between buildings (metres)**	**SD**
The setback distances between the buildings were explored with the respondents' level of visual satisfaction	There was a significant difference at the $p < 0.05$ level in mean setback distance between buildings for the five satisfaction groups: $F(3,46) = 2.99$, $p = 0.04$	Not satisfied	-	
		Somewhat satisfied	4.4	2.77
		Moderately satisfied	4.1	2.69
		Very satisfied	7.3	5.30
		Extremely satisfied	9.4	8.90

6.3.5.2.2 Open space

The open space around 50 buildings was measured during the first field study. The mean open space around the buildings was about 26%, while the minimum open space was 19%, and the maximum open space was 55%. A one-way between-groups analysis of variance (ANOVA) was conducted in SPSS to explore the impact of open space around the buildings (in percentage) on levels of respondents' satisfaction of open space. The levels of satisfaction of open space were divided into five groups (Group 1: not satisfied; Group 2: somewhat satisfied; Group 3: moderately satisfied; Group 4: very satisfied; Group 5: extremely satisfied). The results in Table 6-22 show that there was a significant difference at the $p < 0.05$ level for the actual open space around the buildings and the five groups on open space satisfaction. If the mean open space around the buildings was 45%, respondents were "very satisfied", while a mean open space of 55% resulted in the respondents being "extremely satisfied".

Table 6-22: ANOVA for open space (percentage) and respondents' satisfaction of open space

Analysis	**Findings**	**Satisfaction level**	**Open space around buildings (%)**	**SD**
The open space around the buildings was explored with the respondents' level of satisfaction of open space	There was a significant difference at the $p < 0.05$ level in open space for the five satisfaction groups: $F(4,45) = 17.17$, $p = 0.000$	Not satisfied	19	19.09
		Somewhat satisfied	20	2.99
		Moderately satisfied	25	6.73
		Very satisfied	45	15.35
		Extremely satisfied	55	-

6.3.5.2.3 Size of rooms

As the size of the bedrooms (bedroom 2 and bedroom 3), living rooms and dining rooms did not result in “high” satisfaction, one-way between-groups analysis of variance (ANOVA) was conducted in SPSS to explore the impact of various room sizes of 50 apartments (bedroom 2, bedroom 3, living room and dining room) on levels of respondents’ satisfaction of room sizes. The levels of satisfaction of room sizes were divided into five groups (Group 1: not satisfied; Group 2: somewhat satisfied; Group 3: moderately satisfied; Group 4: very satisfied; Group 5: extremely satisfied). The results in Table 6-23 show that there was a significant difference at the $p < 0.05$ level for the sizes of the bedrooms (bedroom 2 and bedroom 3), living rooms and dining rooms with the five satisfaction groups for room size. If the mean size of the bedroom 2 was 11.68 square metres, respondents would be “very satisfied”, while a mean size of 12.41 square metres resulted in the respondents being “extremely satisfied” of the room size. If the mean size of the bedroom 3 was 11.08 square metres, respondents would be “very satisfied”, while a mean size of 12.71 square metres resulted in the respondents being “extremely satisfied” with the room size. If the mean size of the living room was 12.72 square metres, respondents would be “very satisfied”, while a mean size of 15.58 square metres resulted in the respondents being “extremely satisfied” of the room size. If the mean size of the dining room was 13.24 square metres, respondents would be “very satisfied”, while a mean size of 20.49 square metres resulted in the respondents being “extremely satisfied” with the room size.

Table 6-23: ANOVA for size of rooms and respondents’ satisfaction of room size

Analysis	**Findings**	**Satisfaction level**	**Mean room size (square metres)**	**SD**
Sizes of bedrooms 2 were explored with the respondents’ satisfaction of size of bedroom 2	There was a significant difference at the $p < 0.05$ level in mean size of bedroom 2 for the five satisfaction groups: $F(4,45)= 37.05$, $p= 0.00$	Not satisfied	9.74	0.00
		Somewhat satisfied	9.55	0.23
		Moderately satisfied	10.65	0.34
		Very satisfied	11.68	0.89
		Extremely satisfied	12.41	0.24

Analysis	Findings	Satisfaction level	Mean room size (square metres)	SD
Sizes of bedrooms 3 were explored with the respondents' satisfaction of size of bedroom 3	There was a significant difference at the $p < 0.05$ level in mean size of bedroom 3 for the five satisfaction groups: $F(4,45) = 55.84$, $p = 0.00$	Not satisfied	9.52	0.27
		Somewhat satisfied	9.73	0.28
		Moderately satisfied	10.64	0.39
		Very satisfied	11.08	0.82
		Extremely satisfied	12.71	0.58
Sizes of living rooms were explored with the respondents' satisfaction of size of living room	There was a significant difference at the $p < 0.05$ level in mean size of living rooms for the five satisfaction groups: $F(4,45) = 95.19$, $p = 0.00$	Not satisfied	9.75	0.00
		Somewhat satisfied	10.65	0.49
		Moderately satisfied	11.21	0.63
		Very satisfied	12.72	1.24
		Extremely satisfied	15.58	1.10
Sizes of dining rooms were explored with the respondents' satisfaction of size of dining room	There was a significant difference at the $p < 0.05$ level in mean size of dining rooms for the five satisfaction groups: $F(4,45) = 17.69$, $p = 0.00$	Not satisfied	11.06	0.45
		Somewhat satisfied	11.38	0.00
		Moderately satisfied	11.88	0.97
		Very satisfied	13.24	0.91
		Extremely satisfied	20.49	4.43

6.3.5.2.4 Storage facilities

Figure 6-25a shows the photograph of a storeroom (1.5 square metres) in an apartment, while Figure 6-25b is the photograph of a maidservant's toilet (1 square metre) that is being used as a storeroom because the apartment did not have any storage facility. Figure 6-25c also shows the photograph of a storeroom that was originally designed as toilet, while Figure 6-25d is a photograph of a balcony that is being used as storage space.

(a) (b)

(c) (d)

Figure 6-25: Spaces used for storage

6.3.5.2.5 Efficiency of community spaces

Community spaces in the high-rise residential buildings of Dhaka usually take the form of a hall or on the rooftop. Figures 6-26 are the photographs of community halls in four different buildings. Figures 6-26a, b and c are photographs of community halls on roofs, while Figure 6-26d is the photograph of a community hall on an intermediate floor. It was found that these community halls were only used by the respondents when they required larger spaces to host functions and parties, also confirming the study by Razzaque and Nahid (2007). These community halls were ranked with "medium" level of satisfaction by the respondents probably because they do not provide a sense of community interaction.

(a) (b)

(c) (d)

Figure 6-26: Community spaces

6.3.5.3 Environmental satisfaction

The respondents were asked about the following environmental attributes: day-lighting, natural ventilation, building construction, sound pollution, household waste management and resource management that are likely to affect residential satisfaction, which are discussed in detail in the following sections.

6.3.5.3.1 Day-lighting and natural ventilation

Table 6-24 presents the descriptive statistics together with the Relative Importance Index (RII) and satisfaction level based on RII (high, medium, low) for the perceived day-lighting and natural ventilation affecting residential satisfaction. As none of these environmental aspects on the satisfaction for perceived day-lighting and natural ventilation scored a relative importance index (RII) of 0.75, these aspects have been further analysed.

Table 6-24: Descriptive statistics for day-lighting and ventilation aspects affecting residential satisfaction in 50 apartments

	Min	**Max**	**Mean**	**SD**	**RII**	**Satisfaction level**
Day-lighting in bedrooms	1	5	3.40	0.95	0.68	M
Natural ventilation in the rooms	1	5	3.40	1.20	0.68	M
Day-lighting in kitchen	1	5	2.94	1.24	0.59	M
Day-lighting in living room	1	5	2.68	1.62	0.54	L
Day-lighting in dining room	1	5	2.60	1.46	0.52	L

Day-lighting

The illumination inside the various rooms of 50 apartments was also recorded using a light meter during the first field study. Illuminance readings were taken at four points inside the rooms (bedrooms, living and dining room and kitchen in the 50 apartments) with the artificial lights switched off as shown in Figure 6-27. The first reading (I_o) was taken outside the window to measure the unobstructed horizontal illuminance, while the other three readings were taken to calculate the mean internal (I_i) illuminance inside the rooms. The second reading (I_2) was taken 0.6 metres from the window; the third (I_3) was taken at the centre of the room, while the last reading (I_4) was taken 0.6 metres from the wall opposite the window.

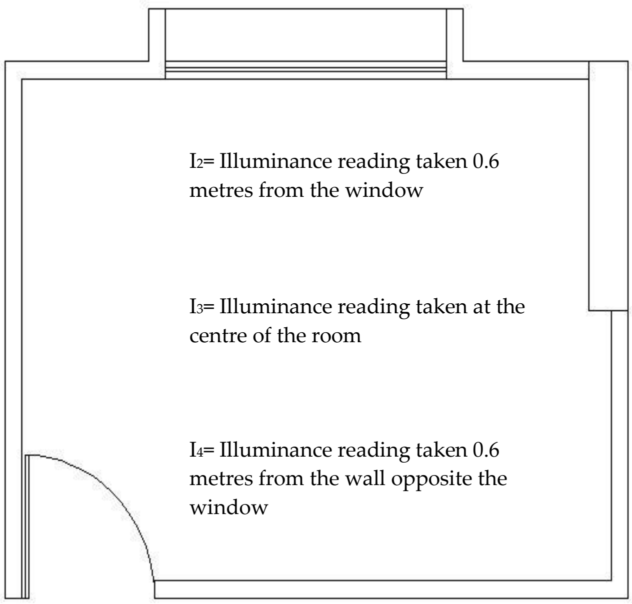


Figure 6-27: Position of illuminance readings in a typical room

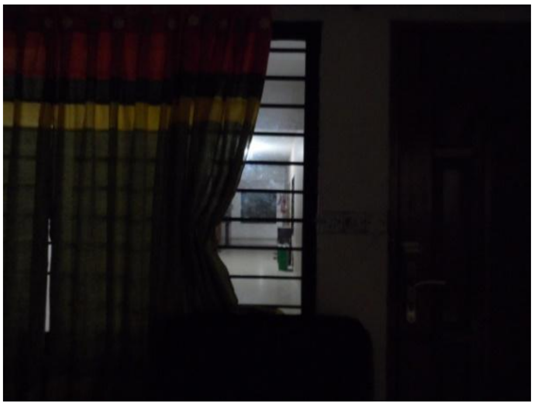
It must be noted that the readings were taken against one window, even though the room might have two windows. The daylight factor, expressed as a percentage, was calculated as the ratio of mean internal illuminance (I_i) to unobstructed horizontal illuminance (I_o). Table 6-25 presents the daylight factor in the various rooms of the apartments.

Table 6-25: Average daylight factor in rooms of 50 apartments

Daylight factor (%)	Min	Max	Mean	SD
Bedroom1	0.07	6.98	2.87	2.06
Bedroom 2	0.26	6.34	2.49	1.68
Bedroom 3	0.10	8.45	1.65	1.59
Living room	-	5.39	1.30	1.20
Dining room	-	4.38	1.15	1.29
Kitchen	0.05	5.53	1.62	1.17

Daylight factors in some living and dining rooms of the apartments could not be measured as these rooms did not have any external opening and hence, the unobstructed horizontal illuminance was zero. Figure 6-28 is the floor plan of a building with six apartments per floor. Dining rooms in apartment 3 and 6 did not have any windows facing external walls, while living rooms in apartments 1, 2, 4 and 5 also did not have any windows facing external walls.

Figure 6-28: Typical floor plan of a building with six apartments per floor



(a)

(b)

Figure 6-29: Rooms with windows that do not face external walls

Figure 6-29a shows a photograph looking towards the corridor from the window of the living room in apartment 5 of the floor plan in Figure 6-28. Similarly, Figure 6-

29b shows a photograph looking towards the elevator from the window of the dining room in apartment 6 of the floor plan in Figure 6-28.

A one-way between-groups analysis of variance (ANOVA) was conducted in SPSS to explore the impact of daylight factor in various rooms of 50 apartments (bedrooms, living rooms, dining rooms and kitchen) with the respondents' satisfaction of day-lighting in the same rooms. The levels of satisfaction of the respondents for the perceived day-lighting in bedrooms, living rooms, dining rooms and kitchens of the apartments were divided into five groups (Group 1: not satisfied; Group 2: somewhat satisfied; Group 3: moderately satisfied; Group 4: very satisfied; Group 5: extremely satisfied). The results of the above mentioned ANOVA analysis are presented in Table 6-26.

Table 6-26: ANOVA for illumination/ daylight factor and respondents' satisfaction of day lighting in different rooms

Analysis	**Findings**	**Satisfaction level**	**Mean daylight factor (%)**	**SD**
Daylight factor in bedrooms was explored with the respondents' satisfaction of day-lighting in bedrooms	There was a significant difference at the $p < 0.05$ level for mean daylight factor in bedrooms for the five satisfaction groups: $F(4,45)= 3.86$, $p= 0.01$	Not satisfied	0	0.00
		Somewhat satisfied	1.2	0.94
		Moderately satisfied	2.2	1.12
		Very satisfied	2.3	1.55
		Extremely satisfied	3.9	1.35
Daylight factor in living rooms was explored with the respondents' satisfaction of day-lighting in living rooms	There was a significant difference at the $p < 0.05$ level for mean daylight factor in living rooms for the five satisfaction groups: $F(4,45)= 3.94$, $p= 0.01$	Not satisfied	0.5	0.80
		Somewhat satisfied	1.5	1.20
		Moderately satisfied	1.4	0.27
		Very satisfied	1.5	0.83
		Extremely satisfied	2.1	1.42
Daylight factor in dining rooms was explored with the respondents' satisfaction of day-lighting in dining rooms	There was a significant difference at the $p < 0.05$ level for mean daylight factor in dining rooms for the five satisfaction groups: $F(4,45)= 4.27$, $p= 0.01$	Not satisfied	0.5	1.10
		Somewhat satisfied	1.0	1.33
		Moderately satisfied	1.0	0.85
		Very satisfied	2.0	1.23
		Extremely satisfied	2.3	1.04
Daylight factor in kitchens was explored with the respondents' satisfaction of day-lighting in kitchens	There was a significant difference at the $p < 0.05$ level for mean daylight factor in kitchens for the five satisfaction groups: $F(4,45)= 64.30$ $p= 0.00$	Not satisfied	0.3	0.31
		Somewhat satisfied	0.8	0.42
		Moderately satisfied	1.6	0.35
		Very satisfied	2.2	0.35
		Extremely satisfied	3.7	0.84

The results in Table 6-26 show that there was a significant difference at the $p < 0.05$ level for daylight factor across different rooms with the five satisfaction groups of day-lighting for the same rooms. It is interesting to find that the respondents tend to be extremely satisfied with day-lighting for higher levels of daylight factor in bedrooms and kitchens compared other rooms such as dining rooms and living rooms. This could be attributed to the fact that the respondents expect the bedrooms to have more daylight and spend more time in the bedrooms during the daytime and therefore prefer higher levels of daylight factor in the bedrooms. The preference of the respondents to have more daylight can also be proven through the findings in Section 6.3.3.2, where it was shown that about 98% of the apartments surveyed had two windows in bedroom 1, while 42% and 32% of the apartments had two windows in bedroom 2 and bedroom 3 respectively. Compared to bedrooms, only 34% of the apartments had two windows in living rooms, while none of the apartments had two windows in dining rooms. The presence of two windows in bedroom 1 (the master bedroom) is suggestive of that priority given to the daylight in it. Kitchens are also preferred to have higher illumination level because they are generally used frequently throughout the daytime for cooking. The respondents were extremely satisfied with the day-lighting in dining rooms and living rooms at lower values of daylight factor compared to those of bedrooms and kitchens most likely because these rooms are not occupied frequently during the daytime. Living rooms are generally used during the evenings for watching television and entertaining guests.

The daylight factor in the apartments was found by taking the mean of all the rooms' daylight factor. The mean daylight factor was 2% (SD= 0.7). A linear regression analysis was conducted in SPSS to analyse the influence of different design characteristics such as apartment size, floor level, window area, total shading depth and effective canyon ratio, on the daylight factor in the 50 apartments. According to the model, out of all the five design characteristics investigated, total window area explains 16% (R^2 =0.16, p= 0.00) of the variance in average daylight factor in the apartments. Only total window area was the statistically significant predictor at the $p < 0.05$ level that influenced daylight factor. The sign of the predictor in the regression model showed that mean daylight factor increased with an increase in total window area.

Perceived natural ventilation

A linear regression analysis was conducted in SPSS to analyse the influence of different design characteristics such as apartment size, floor level, total window area, total shading depth and effective canyon ratio, the respondents' satisfaction of perceived natural ventilation. According to the model, out of all the five design characteristics investigated, floor level explains 62%% (R^2 =0. 62, p= 0.00) of the variance in satisfaction of perceived natural ventilation by the respondents in the apartments. Only floor level was the statistically significant predictor at the $p < 0.05$ level that influenced respondents' satisfaction of perceived natural ventilation. The sign of the predictor in the regression model showed that respondents' satisfaction of perceived natural ventilation increased as floor level increased. This could be explained by the fact that occupants on higher floors tend to open their windows more, compared to the occupants on lower floors where they seldom open the windows due to lack of privacy.

6.3.5.3.2 Building construction

Building construction attributes based on the respondents' perception that were likely to influence satisfaction of high-rise living included the two aspects, structural safety and construction quality of the building. Results in Table 6-27 shows that the respondents expressed "low" levels of satisfaction for both these aspects.

Table 6-27: Descriptive statistics for the building construction aspects affecting residential satisfaction in 50 apartments

	Min	**Max**	**Mean**	**SD**	**RII**	**Satisfaction level**
Construction quality of the building	1	5	2.58	0.86	0.52	L
Structural safety of the building	1	5	2.52	0.84	0.50	L

6.3.5.3.3 Sound pollution

Environmental attributes which play an important role in facilitating satisfaction with living in high-rise residential buildings include aspects such as noise control in the apartments. The respondents were asked about their satisfaction on noise level in the apartments. The results show that the respondents expressed "low" level of satisfaction with noise in the apartments (M=2.64, SD=1.24).

The noise inside all the rooms of 50 apartments was measured with a sound meter in the daytime during the second field study, to measure the internal noise level in each room with as is conditions (windows closed/open). The mean internal noise level was found by taking the average value of the readings (in dBA) inside all the rooms in an apartment. The mean internal noise level in 50 apartments was 35.34 dBA, with of a minimum of 30 dBA and maximum noise 57 dBA (SD=5.20). It must be noted that while the mean internal noise level inside the apartments was found to be 35.34 dBA, the limit of acceptable internal noise level according to GoB (2006) during the daytime in residential areas is 55 dBA. The Noise Pollution Control Act of GoB (2006) does not, however, specify what the noise limit should be inside the bedrooms and other habitable rooms.

It is acknowledged that even though sound transmission and acoustic privacy (audible sounds) are also factors that can affect satisfaction on the acoustic quality in a space, they could not be addressed due to limitations of measurement and the scope of this research.

A one-way between groups analysis of variance (ANOVA) was conducted to explore the effect of internal noise levels in the apartments on respondents' satisfaction of noise level in the apartments (Table 6-28). The results of Table 6-28 show that there was a significant difference at the $p < 0.05$ level for average internal noise level and the five satisfaction groups for noise level in the apartments. The results showed that the respondents were "very satisfied" with an average internal noise level of 31.3 dBA and "extremely satisfied" when the mean internal noise level was 30.5 dBA.

Table 6-28: ANOVA for internal noise and respondents' satisfaction of noise level in the apartment

Analysis	Findings	Satisfaction level	Mean internal noise level (dBA)	SD
Internal noise in all the apartments was explored with respondents' satisfaction with the noise level in the apartment	There was a significant difference at the $p < 0.05$ level of mean internal noise in the apartments for the five satisfaction groups: $F(4,45) = 20.61$ $p = 0.000$	Not satisfied	41.8	5.61
		Somewhat satisfied	36.0	2.74
		Moderately satisfied	33.2	1.42
		Very satisfied	31.3	0.63
		Extremely satisfied	30.5	0.71

A correlation between the mean internal noise level and floor level showed a significant negative correlation (R^2=0. 27, p= 0.00), implying that the mean internal noise level decreased with the increase in floor levels. This confirms the claims by the respondents that less noise was one of the advantages of high-rise living. In order to find out how the mean internal noise level in the apartments varied across the different floor groups, a one-way between groups analysis of variance (ANOVA) was conducted (Table 6-29). The floors were divided into four groups (Group 1: 1-6; Group 2: 7-10; Group 3: 11-15; Group 4: 16-20). The results of Table 6-29 show that there was a significant difference, at the $p < 0.05$ level, for the analysis between mean internal noise level and the floor groups. The results show that the mean internal noise level reduced with an increase in floor groups. The mean internal noise level appeared to be better (i.e less) on floor groups 11-15 (32.63 dBA) and 16-20 (34.56 dBA) compared to floor groups 1-6 (41.57 dBA) and 7-10 (35.62 dBA). The higher noise level occurring at higher levels (16-20) is seemingly anomalous and can be explained by the fact that at higher levels occupants tend to have more windows open.

Table 6-29: ANOVA for noise levels across different floor groups

Analysis	**Findings**	**Floor levels**	**Mean internal noise level (dBA)**	**SD**
Relationship between mean internal noise in the apartments and floor levels	There was a significant difference at the $p < 0.05$ level of mean internal noise in the apartments and the floor levels: $F(3,49) = 9.19$ $p = 0.00$	1-6	41.57	7.72
		7-10	35.62	3.12
		11-15	32.63	2.67
		16-20	34.56	3.57

6.3.5.3.4 Household waste and resource management

Household waste collection is an environmental attribute which plays an important role in facilitating satisfaction of living in high-rise residential buildings. The respondents were asked about their satisfaction level on household waste management in the buildings. The results show that the respondents expressed "medium" level of satisfaction with household waste management (M=3.42, SD=0.68).

Resource management includes management of electricity, water and gas. Resource management attributes which are likely to create an impact on the satisfaction of living in high-rise residential buildings include variables such as backup power generation services, provision of storage for rainwater, provision of water efficient fixtures and fittings and metering systems for electricity, gas and water usage. Table 6-30 presents the descriptive statistics together with the Relative Importance Index (RII) and satisfaction level based on RII (high, medium, low) for the resource management aspects affecting residential satisfaction.

Table 6-30: Descriptive statistics for the resource management aspects affecting residential satisfaction in 50 apartments

	Min	**Max**	**Mean**	**SD**	**RII**	**Satisfaction level**
Backup power generation	1	4	3.18	0.77	0.64	M
Metering systems for electricity usage	1	4	3.02	0.89	0.60	M
Metering systems for gas usage	1	4	2.16	1.02	0.43	L
Metering systems for water usage	1	4	1.96	1.01	0.39	L
Provision of water efficient fixtures	1	3	1.44	0.67	0.29	L
Provision of storage and reuse of rainwater	1	1	1.00	0.00	0.20	L

Of the six different resource management aspects that were investigated to understand residential satisfaction, none of the aspects received “high” satisfaction. Backup power generation during electricity outages and metering systems for electricity usage were the only two resource management aspects that reached “medium” satisfaction amongst the respondents. The results also show that the metering systems for gas and water usage, water efficient fixtures and storage of rainwater received “low” satisfaction.

6.3.6 Concerns of high-rise living

Based on the literature review in Chapter 3, the general concerns about high-rise living were identified as building height, lack of neighbourhood facilities, lack of playing space for children, lack of visual privacy, lack of social interaction, who are the neighbours, emotional stress or mental health difficulties, behavioural problem in children, problems in children’s development, accidental falls of family members, leaping from high-rise buildings as suicidal attempts, travel time in elevator, crime in corridor, crime in the elevator, elevator breakdown, fire risk, structural safety and power failure (leading to water crisis). In the second household questionnaire survey of the 50 apartments, the respondents were asked to rank these concerns. All the responses to these concerns were based on a five point Likert scale, where “1” indicated “not concerned” and “5” indicated “extremely concerned”.

In addition to these concerns, apartment rent and monthly expenses on utility services were requested to be ranked in this questionnaire survey. Apartment rent and monthly expenses on utility services were included to explore whether the rent of the apartments and monthly expenses for the various utility services in the high-rise residential buildings were concerns among the respondents, as data from the first household survey had revealed that the rent level varied between “about right” to “high”, while monthly expense level for utility services varied between “very high” to “extremely high”.

Table 6-31 presents the descriptive statistics together with the Relative Importance Index (RII) and concern level based on RII (high, medium, low) for the general concerns of high-rise living. The results show that fire risk, structural safety, lack of playing space for children, elevator breakdown, power failure, lack of social interaction, lack of visual privacy and water crisis had a “high” level of concern. Apartment rent and monthly expenses for utility services were not of “high” concerns among the respondents. It is interesting to note that fire risk, structural safety, elevator breakdown, power failure and water crisis were among the seven disadvantages of high-rise living as reported by the respondents during the first household questionnaire survey.

Table 6-31: Descriptive statistics for concerns of high-rise living in 50 apartments

	Min	Max	Mean	SD	RII	Concern level
Fire risk	4	5	4.88	0.33	0.98	H
Structural safety	4	5	4.82	0.39	0.96	H
Lack of playing space for children	3	5	4.02	0.59	0.80	H
Elevator breakdown	2	5	3.92	0.85	0.78	H
Power failure	2	5	3.86	0.93	0.77	H
Lack of social interaction	2	5	3.84	0.68	0.77	H
Lack of visual privacy	2	5	3.82	0.63	0.76	H
Water crisis	3	5	3.78	0.68	0.76	H
Monthly expenses for utility services	1	5	3.64	1.01	0.73	M
Apartment rent	2	5	3.42	0.99	0.68	M
Lack of neighbourhood facilities	1	5	2.86	1.01	0.57	M
Building height	1	4	2.68	0.79	0.54	L
Crime in the elevator	1	4	2.54	0.91	0.51	L
Who are the neighbours	1	4	2.46	0.79	0.49	L
Crime in corridor	1	5	2.36	0.96	0.47	L
Accidental falls of family members	1	4	2.32	0.96	0.46	L
Travel time in elevator	1	4	2.22	0.99	0.44	L
Problems in children’s development	1	2	1.74	0.44	0.35	L
Emotional stress or mental health difficulties	1	3	1.48	0.58	0.30	L
Behavioural problem in children	1	3	1.40	0.67	0.28	L
Leaping from high-rise buildings as suicidal attempts	1	3	1.36	0.53	0.27	L

A comparison of these high-rise living concerns in Dhaka with those in Hong Kong and Singapore (Yeh & Yuen 2011) reveal that fire risk and elevator breakdown are ranked among the top six concerns in these two countries.

6.3.7 Behavioural aspects

The questions on behavioural aspects of the first household questionnaire survey were categorised in two sections. The questions in the first section were designed to examine the willingness and affordability of the respondents to have/use some design features and facilities. The second section consisted of questions that studied the willingness of the respondents to undertake educational and training programs on fire safety, emergency preparedness during natural disasters (such as earthquake), efficient electricity use, efficient water use and efficient household waste management. The responses of the respondents to the questions in both sections were based on a five point Likert scale, where “1” indicated “very unlikely”, “2” indicates “unlikely”, “3” indicated “somewhat likely”, “4” indicated “likely” and “5” indicated “very likely”. Table 6-32 presents the descriptive statistics for the willingness given by the respondents for the 17 design features and facilities. Out of the 17 design features and facilities, 13 design features and facilities received “high” level of willingness as shown in the shaded regions of Table 6-32.

Table 6-32: Descriptive statistics for the willingness of the respondents in 117 apartments to have/use 17 design features and facilities

	Min	**Max**	**Mean**	**SD**	**RII**	**Willingness level**
Willingness to have (pay for) more fire security measures	4	5	4.88	0.33	0.98	H
Willingness to have (pay for) more security measures at the building entrance, apartment and common spaces	3	5	4.79	0.43	0.96	H
Willingness to have (pay for) energy efficient lighting system	3	5	4.69	0.68	0.94	H
Willingness to have (pay for) water efficient fixtures and fittings	3	5	4.64	0.53	0.93	H
Willingness to have (pay for) the provision of design consideration for the disabled and elderly people	4	5	4.51	0.50	0.90	H
Willingness to have (pay for) elevators, large enough to fit a wheelchair and stretcher	2	5	4.37	0.66	0.87	H
Willingness to have (pay for) the provision of playing space for children	3	5	4.33	0.64	0.87	H
Willingness to have (pay for) the provision of well-designed interactive community spaces	2	5	4.09	0.73	0.82	H
Willingness to have (pay for) the provision of inspections for maintenance purposes	2	5	4.07	0.81	0.81	H

	Min	Max	Mean	SD	RII	Willingness level
Willingness to use rainwater and grey water	1	5	3.92	0.98	0.78	H
Willingness to have (pay for) the provision of for gym and game facilities	1	5	3.84	0.97	0.77	H
Willingness to have (pay for) the provision of more open space	2	5	3.79	0.83	0.76	H
Willingness to have (pay for) the provision of roof gardens	1	5	3.76	1.06	0.75	H
Willingness to have (pay for) the provision of electrical sub-metering for major consuming devices to monitor electricity usage	1	5	3.15	1.39	0.63	M
Willingness to have (pay for) electrical appliances that have energy star ratings	1	5	3.10	1.18	0.62	M
Willingness to pay for the additional cost for the secondary energy source	1	5	2.48	1.02	0.50	L
Willingness to collect waste in 3 different bins	1	5	2.43	1.12	0.49	L

Out of the remaining four facilities: willingness to have (pay for) the provision of electrical sub-metering for major consuming devices to monitor electricity usage and willingness to have (pay for) electrical appliances that have energy star ratings received “medium” level of willingness, while a willingness to pay for the additional cost for the secondary energy source and willingness to collect the waste in 3 different bins received “low” level of willingness.

Table 6-33 presents the descriptive statistics together with the RII and relative importance of the responses given by the respondents to their willingness to undertake educational and training programs. The results in Table 6-33 show that the respondents gave “high level of willingness” to all six educational and training programs on fire safety, emergency preparedness during natural disasters such as earthquake, efficient electricity, water and gas management and efficient household waste management.

Table 6-33: Descriptive statistics for the willingness of the respondents in 117 apartments to undertake educational and training programs

Training and educational programs	Min	Max	Mean	SD	RII	Willingness level
Emergency preparedness during natural disasters such as earthquake	3	5	4.63	0.52	0.93	H
Fire safety	3	5	4.57	0.53	0.91	H
Efficient electricity management	2	5	4.08	0.84	0.82	H
Efficient water management	2	5	4.02	0.82	0.80	H
Efficient gas management	2	5	4.00	0.87	0.80	H
Efficient household waste management	2	5	3.97	0.87	0.79	H

In order to explore the correlations between the questions on the willingness of respondents to undertake educational and training programs on efficient electricity, water, gas and household waste management and the previously discussed questions on public awareness programs (on electricity, water and gas conservation and household waste management programs) in Section 6.3.2.7, a cross tabulation in SPSS was further conducted.

The relationship between the respondents' awareness of electricity conservation and their willingness to undertake educational and training programs on efficient electricity management showed no statistically significant difference when a cross tabulation was conducted between these two variables, c^2 (1, N=116) = 0.12, p= 0.99. Among the 72% of the respondents who had not heard of awareness programs on electricity conservation, 40% were "likely" to receive training on efficient electricity management, while 36% were "very likely" to receive it. Among the 28% of the respondents who had heard of awareness programs on electricity conservation, 42% were "likely" to receive training on efficient electricity management, while 33% were "very likely". It can be concluded that respondents were willing to receive training on efficient electricity management regardless of whether they were aware or unaware of electricity conservation programs.

Similarly, no statistically significant difference was observed in the response between the respondents' awareness on water conservation and their willingness to receive training on efficient water management, when a cross tabulation was conducted between these two variables, c^2 (1, N=116) = 5.83, p= 0.12. Among the 92% of the respondents who had not heard of awareness programs on water conservation, 42% ranked their willingness to receive training on efficient water management as "likely", while 34% were "very likely". Between 8% of the respondents who had heard of awareness programs on water conservation, 56% were "likely" to receive training on efficient water management. It can thus be concluded that respondents were willing to receive training on efficient water management regardless of whether they were aware or unaware of water conservation programs.

The relationship between the respondents' awareness of gas conservation and their willingness to undertake educational and training programs on efficient gas management use showed no statistically significant difference when a cross tabulation was conducted between these two variables, c^2 (1, N=116) = 0.54, p= 0.91. Among the 93% of the respondents who had not heard of awareness programs on gas conservation, 40% were "likely" to receive training on efficient gas management, while 32% were "very likely" to receive it. Among the 7% of the respondents who had heard of awareness programs on gas conservation, equal number of people were both "likely" and "very likely" to receive training on efficient gas management. It can be concluded that respondents were willing to receive training on efficient gas management regardless of whether they were aware or unaware of gas conservation programs.

There was also no statistically significant difference in the response between the respondents' awareness on household waste management and their willingness to receive training on efficient management of this; when a cross tabulation was conducted between these two variables, c^2 (1, N=116) = 3.56, p= 0.31. Between 93% of the respondents who had not heard of awareness programs on household waste management, 43 % were "likely" to receive training on efficient household waste management, while 30% were "very likely". Between 7% of the respondents who had heard of awareness programs on household waste management, 13% were "likely" to receive training on efficient household waste management, while 50% were "very likely". It can therefore be concluded that respondents were willing to receive training on efficient household waste management regardless of whether they were aware or unaware of such household waste management programs.

6.3.8 Discussion

6.3.8.1 General

This chapter first discussed the social and environmental issues of high-rise living in Dhaka. It was then followed by discussions of the building attributes that are likely to the affect satisfaction of high-rise living, the concerns with high-rise living and the behavioural aspects of the respondents of the high-rise residential buildings. The pull factors of high-rise living included better natural ventilation (confirmed by statistical test), ample day lighting, better security and less noise (also confirmed by statistical test). This is in agreement with the findings of Yuen et al. (2006) for high-rise living in Singapore.

Lack of safety during fire, fear of structural safety and difficulty using stairs when the elevators are not working and when there is no electricity, and water supply problem when there is no electricity were both the drawbacks and concerns of high-rise living, in addition to social interaction being a concern. It is interesting to note that among the “high ” concerns of high-rise living in Dhaka, fire risk and elevator breakdown were also among the top six concerns in Hong Kong and Singapore (where the remaining top four are: who are the neighbours, crime in the elevator, accidental falls of family members and lack of neighbourhood facilities). Even though behavioural problem in children, crime in the elevator and corridor, mental health problems, suicidal attempts by jumping from high-rise residential buildings were reported in other studies around the world, these issues are of low concern in Dhaka.

6.3.8.2 Building height

It was found that building height was not a restricting factor of high-rise living. 96% of the respondents considered buildings between 11-15 storeys as tall buildings, while 64% respondents considered buildings between 11-15 storeys as very tall buildings. The highest preferred floor level was between 11-15 storeys, compared to 26-30 storeys for Hong Kong and Singapore (Yeh and Yuen 2011). As anticipated, respondents with lower household income, expressed that the rent they pay is high, compared to the respondents with higher household income who said that the rent was about right. No relationship was found between apartment rent and floor level. This is in contrast to the situation in Hong Kong, where apartment prices and rentals for higher floors were much higher than lower floors (Yeh and Yuen 2011).

6.3.8.3 Neighbourhood facility

Availability of neighbourhood facilities also scored “medium” level of satisfaction because not all the neighbourhood facilities that were highlighted with a high level of importance (supermarket, pharmacy/medicine store, grocery shops, rickshaw/auto-rickshaw stand, mosque/worship place, playground, doctor’s chamber, waste transfer station, technician services, park and laundry) were found during the physical survey of the neighbourhoods of the five case study buildings. Playgrounds, municipal waste collection points and parks were not present in the neighbourhoods even though they were ranked with “high” importance.

6.3.8.4 Setback

Visual privacy from the exterior scored “medium” level of satisfaction, as the setback distance between the buildings was not adequate to promote visual privacy in the apartments from neighbouring buildings. Analysis showed that a setback distance of 7.3 to 9.4 metres improved satisfaction with visual privacy.

6.3.8.5 Open space

Respondents ranked “low” level of satisfaction with the amount of open space in the building premises; hence, they wanted more open space. Analysis showed that 45 % to 55% of open space in building premises, enhanced satisfaction in this regard. It must also be added that according to the stakeholders in Chapter 5, open space should be about 53%. Respondents also ranked “low” level of satisfaction with the playing space for children, as the majority of children played indoors and in parking spaces. Respondents were willing to pay for the provision of open space and playing space for children.

6.3.8.6 Social interaction

Space for interaction with neighbours was ranked with "low" level of satisfaction, and lack of social interaction was considered a concern of high-rise living among the respondents. It was found that the majority of the respondents interacted with each other while travelling in the elevators, walking up and down the stairs and while walking towards their apartment in corridors. It was also found that a compact floor plan with lesser number of apartments facing each other, and with sufficient daylight and natural ventilation induced more interaction in the corridors, staircases and elevator lobbies.

An analysis between the responses of the respondents on satisfaction of space for interaction with neighbours and their level of concern on lack of social interaction were conducted to investigate if indeed better results emanated where flats had better interaction. However, the results did not show any significant relationship.

The respondents ranked "medium" level of satisfaction for the efficiency of the "so called" community spaces because of the lack of community interaction in those spaces. It was also found that respondents were willing to use, maintain and pay for the provision of well-designed interactive community spaces and roof gardens. These spaces could be designed to promote social interaction among the respondents. In addition to facilities such as community space, the respondents had also enunciated "high" level of willingness to use, maintain and pay for the provision of a gym with indoor game facilities.

6.3.8.7 Design for elderly and disabled

The respondents scored "low" level of satisfaction with design features for the elderly and disabled, as none of the apartments and buildings surveyed had the provisions of design features such as ramps, hand rails in toilets and bathrooms for the elderly and disabled, while only two buildings had elevators large enough to fit wheelchairs and stretchers. The respondents were found willing ("high" level of willingness) to pay for the provision of design consideration for the disabled and elderly people, and pay for elevators large enough to fit a wheelchair and stretcher.

6.3.8.8 Security

Out of the different surveyed social attributes of high-rise living, security within the building scored a “high” level of satisfaction. Even though the respondents expressed a “high” level of satisfaction of security within the building, analysis shows the need to have even better safety and security measures for users to access the building and the willingness to pay for more security measures at the building entrance, in apartments and common spaces.

6.3.8.9 Space requirements

Among design attributes focused on the study of 50 apartments with three bedrooms, it was found that respondents ranked “high” level of satisfaction to the size of bedroom 1 (mean size being 13 square metres), kitchen (mean size being 7.33 square metres) and toilet, aesthetic appearance of the building, room layout plan, interior design, orientation of rooms, efficiency of usable area, design of bathroom facilities and kitchen facilities. As the size of the other bedrooms (bedroom 2 and bedroom 3), living rooms and dining rooms did not result in “high” satisfaction, they were analysed further to determine the size of each of the rooms that would result in respondents’ satisfaction. Analyses showed that the respondents were “very satisfied” to “extremely satisfied” when the size of bedroom 2 varied from 11.7 square metres to 12.4 square metres and “very satisfied” to “extremely satisfied” when the size of bedroom 3 varied from 11.1 to 12.7 square metres. Analyses also showed that the respondents were “very satisfied” to “extremely satisfied” when the size of living room varied from 12.7 square metres to 15.6 square metres, and “very satisfied” to “extremely satisfied” when the size of dining room varied from 13.2 to 20.5 square metres.

Toilets and balconies in some apartments were transformed into storage spaces because those apartments did not have any storerooms. In order to achieve satisfaction regarding storage space, apartments must be provided with a minimum of 1.5 square metres for this purpose.

6.3.8.10 Fire safety

Fire safety in the buildings was considered both a drawback and concern of high-rise living. Fire safety scored “low” level of satisfaction as fire-safety provisions did not conform to the standards laid out in the Bangladesh National Building Code (BNBC). Respondents expressed “high” level of willingness to pay for more fire-safety measures and undertake educational and training programs for fire safety.

All building services, particularly fire-fighting facilities and elevators, need regular maintenance as these two services (out of the nine building services investigated) received “low” level of maintenance and the remaining seven were ranked with “medium” level of maintenance. Regular inspections of the building services were ranked with “low” level of satisfaction because most of the buildings surveyed were not regularly inspected. This explains why elevator breakdown was considered as a concern with high-rise living by the respondents. The respondents were found willing to pay for the provision of periodic inspections for maintenance purposes provided. It should also be noted that both owners of the apartments and tenants were willing to pay for the provision of these periodic inspections.

6.3.8.11 Structural safety and construction quality

Structural safety was considered both a drawback and concern of high-rise living and it scored “low” level of satisfaction. This fear of structural safety was reiterated once again when the respondents enunciated “low” level of satisfaction about the construction quality of the buildings. Another drawback of high-rise living associated with the fear of structural safety was the possibility of evacuation problems during disasters. In order to respond rapidly and decisively during natural disasters, the respondents expressed “high” level of willingness to undertake training and educational programs on emergency preparedness during natural disasters, such as an earthquake.

6.3.8.12 Daylight and natural ventilation

The daylight factor in living rooms, dining rooms and kitchens was lower than in the three bedrooms. Further analysis showed that the daylight factor in bedrooms must be between 2.3% to 3.9% to have a satisfaction level in the range “very good” to “excellent”, and in living rooms must be between 1.5% and 2.1% to have a satisfaction level in the range “very good” to “excellent”. The daylight factor in dining rooms must be between 2.0% and 2.3% to have a satisfaction level in the range “very good” to “excellent”, and in kitchens must be between 2.2% and 3.7% to be in the range “very good” to “excellent”. Compared to these daylight factors for satisfaction in various rooms, the recommendations for average daylight factor in residential buildings of Hong Kong are at least 1%, 1.5% and 2% for bedrooms, living rooms and kitchens (Li et al. 1999).

Average daylight and the respondents’ satisfaction with natural ventilation in the apartments were found to be better on higher floors and in neighbourhoods with less effective canyon ratio. The respondents’ satisfaction with natural ventilation improved from floor groups 11-15 onwards, and it was best in floor groups 16-20.

6.3.8.13 Noise

The mean background noise level inside the apartments was found to be 35.3 dBA. Further analysis showed that respondents were “very satisfied” when the mean internal noise level was 31.3 dBA and “extremely satisfied” when the mean internal noise level was 30.5 dBA. The mean internal noise level in the apartments was found to be correlated to floor levels. The mean internal noise level was found to be less on floor levels 11-15 (32.6 dBA) and 16-20 (34.6 dBA), compared to floor levels 1-6 (41.6 dBA) and 7-10 (35.6 dBA).

6.3.8.14 Resource management

None of the surveyed six resource management aspects of high-rise living had scored a “high” level of satisfaction. Power failure and water crisis were considered as concerns with high-rise living. During frequent power outages, backup power supply arrangements (standby gas-run generators) for running elevators and supplying water to the apartments get exhausted and do not function. During such occasions of extreme power outage, when elevators do not operate, occupants have no other alternative but to use the stairs. The situation becomes particularly difficult for aged occupants. This explains why 15 respondents cited difficulty in using the stairs when there was no electricity as one of the drawbacks of high-rise living. As water cannot be supplied in the apartments at times when the backup power supply arrangements fail, the occupants have to collect water from a reservoir situated on the ground floor. This explains why seven respondents had referred to the water supply problem when there were power outages as one of the disadvantages of high-rise living.

The respondents were not satisfied with the water and gas metering systems, as 74% and 63% of the apartments did not have any metering systems for gas and water usage respectively. Despite the fact that the apartments had electricity metering systems, the respondents were not satisfied with these, probably because digital electricity meters were found in only 60% of the apartments. Among the apartments surveyed and buildings surveyed, only one apartment had water saving taps, eight apartments had water saving flushes, and none of the buildings had the provision for storage and reuse of rainwater. Therefore, this explains why the respondents were not satisfied with the provision of water efficient fixtures and rainwater storage facility. It was also found that respondents were willing at a “high” level to pay for and use water efficient fixtures, fittings and rainwater.

Standalone solar photovoltaic (PV) could be deployed on the high-rise residential building rooftops to generate electricity to be used as backup power; however, the respondents ranked “low” level of willingness in response to whether they would be willing to bear the additional cost for this secondary energy source (solar photovoltaic). The use of solar photovoltaic (PV) can only be a reality if the equipment was locally available and affordable. Interestingly, even though the respondents expressed their willingness as “low” to bearing the additional cost of secondary energy sources, and willingness at “medium” level to have and pay for the provision of electrical sub-metering and electrical appliances that have energy star ratings, they articulated a “high” level of willingness to use and pay for energy efficient lighting systems. The respondents also showed “high” level of willingness to take part in training and educational programs for efficient use of resources (electricity and water).

6.3.8.15 Waste management

Even though the respondents expressed "medium" level of satisfaction with household waste management, they showed "low" level of willingness to collect waste in three different bins. However, the respondents articulated willingness to take part in training and educational programs for efficient household waste management. It must also be noted that though the respondents only expressed "low" level of satisfaction to collect waste in three different bins, the stakeholders had expressed "high" level of importance to waste bins of appropriate size for organic waste, recyclables and non-recyclables.

6.4 Chapter Summary

The findings in this chapter imply that in order to meet the needs and satisfaction of the respondents of high-rise residential buildings, the following need to be considered:

1. Supermarket, pharmacy/medicine store, grocery shops, rickshaw/auto-rickshaw stand, mosque/worship place, playground, doctor's chamber, waste transfer station, technician services, park and laundry need to be present in the neighbourhoods of high-rise residential buildings.
2. The visual privacy from the neighbouring apartments/ buildings can be improved if the setback distance between the buildings/apartments is between 7.3 to 9.4 metres.
3. The open space in the building premise should vary from 45% to 55%.
4. The floor plans need to be compact with sufficient daylight, natural ventilation and with apartments facing each other to induce more interaction among the respondents in the corridors, staircases and elevator lobbies.
5. The community space should not be just a "hall". It should be designed in a way to promote social interaction. Roof spaces can be used as spaces for

interaction and outdoor recreation areas. Gym with indoor game facilities should also be provided.

6. The building and the apartments should have the necessary design features such as ramps, handrails in toilets and bathrooms for the elderly and disabled. Elevators should be large enough to fit a wheelchair and stretcher
7. More community safety and security measures must be employed to make the respondents feel safer.
8. The size of the first bedroom (master bedroom) should be larger than the size of the second bedroom.
9. The size of the second bedroom should be between 11.7 to 12.4 square metres, while the size of the third bedroom should be between 11.1 to 12.7 square metres.
10. The size of the living room should be between 12.7 to 15.6 square metres.
11. The size of the dining room should be between 13.2 to 20.5 square metres.
12. The apartments must be provided with a minimum of 1.5 square meters of storage space.
13. The fire-safety provisions should conform to the standards laid out in the Bangladesh National Building Code (BNBC) and the respondents should be educated and trained in fire-safety.
14. All building services, particularly fire-fighting facilities and elevators, need regular maintenance. The building authority should include a maintenance program with regular periodic inspections.
15. Structural safety and construction quality should not be compromised under any circumstances.
16. The daylight factor in bedrooms must be at least 2.3%, in the living rooms at least 1.5%, in the dining rooms at least 2% and at least 2.2% in the kitchens.
17. As the respondents' satisfaction with natural ventilation in the apartments was found to be better on higher floors, the lower floors of the buildings should be designed for mixed-use purposes which are not entirely dependent on natural ventilation.

18. The mean internal noise level in the apartments should not exceed 31 dBA.
19. As the mean internal noise level was found to be less on floor levels 11-15 (32.6 dBA) and 16-20 (34.6 dBA) compared to floor levels 1-6 (41.6 dBA) and 7-10 (35.6 dBA), the floors on 1-10 should have more noise insulation.
20. The apartments should have digital electricity, water and gas meters.
21. The apartments should have water efficient fixtures, fittings and appliances.
22. The buildings must use rainwater harvesting.
23. The buildings must use grey water.
24. The apartments must have energy efficient lighting systems.
25. Standby power generators should be provided to support elevator use during power failures.
26. The respondents must be educated and trained to use resources efficiently (electricity and water). They must also be trained and educated about efficient household waste management, fire safety and emergency preparedness during natural disasters such as earthquake.

Though this chapter discussed some issues regarding resource management, particularly power failure, which occurs due to inadequate power generation capacity of the existing power plants, they were not based on the actual usage of electricity. The next chapter will discuss about the actual electricity consumption of the high-rise apartments in order to explore the factors that affect electricity use in high-rise apartments.

7 Electricity Use in High-rise Apartments

7.1 Introduction

As discussed in Chapter 3, energy used by residential buildings in Dhaka account for more than 50% of the total electricity consumption and high-rise residential buildings contribute to a high proportion of it. Reduction of electricity use from high-rise residential buildings can have a significant impact on total electricity consumption, therefore it is important to identify factors that affect this electricity use.

This chapter examines the influence of three major factors that are known to have an impact on electricity use in buildings: external conditions, design characteristics and the occupants, as discussed in Chapter 3, Table 3-1. The impacts of these factors on both annual electricity use, annual cooling electricity use and annual air-conditioning electricity use are investigated and discussed.

7.2 Methods

In order to identify the factors that can have significant impact on the electricity use in existing high-rise apartments in Dhaka, the research applied a case study method. The selection of the case study buildings was based on the following criteria:

- The buildings were representative of typical multi-unit high-rise residential apartments in Dhaka;
- Data for one year of electricity use from January 2012 to December 2012 were available;

- The buildings were accessible; and
- The architectural drawings of the apartments were available.

The researcher was able to collect electricity use data from 342 high-rise apartments in 8 case study buildings that met the above criteria. In this research, the external conditions were represented by apparent temperatures. According to Steadman (1994), apparent temperature is a general term for the perceived outdoor temperature, as a result of the combined effects of air temperature, relative humidity and wind speed and is shown in the equation below:

$$AT = Ta + 0.33x\ e - 0.70x\ ws - 4.00 \ldots\ldots \quad \mathbf{[7\text{-}1]}$$

Source: Steadman 1994

Where, AT = apparent temperature;
Ta= Dry bulb temperature (°C);
e = Water vapour pressure (hPa); and
ws = wind speed (m/s) at an elevation of 10 meters.

Findings from the literature review in Chapter 3 identified six design characteristics that can play a role in influencing electricity use in high-rise residential buildings. These design characteristics include floor level, apartment size, total window area, total shading depth, shape coefficient of the apartments and the effective canyon aspect ratios around each building.

All the six design characteristics of the 342 apartments were studied while the electricity use records were collected. It should be noted that, as residential buildings in Dhaka have the same building materials, i.e. un-insulated brick walls and single glazed windows, glazing type and thermal insulation were not included in the study, although they were noted. Similarly, as the ceiling height of high-rise residential buildings or any residential building does not vary and is typically 3 metres, the volume of the apartments was also not included.

The occupants of these 342 apartments were contacted again during the fourth step of this research (refer to Section 1.7) to obtain further information on the following:

- Household characteristics such as household size and number of air conditioners and
- Household practices such as air conditioning usage time and preferred set-point temperatures of air conditioners.

Out of the 342 apartments, data on the household characteristics were obtained from 100 apartments, data on household appliances were obtained from 50 apartments and data on the household practices were acquired from 36 apartments as mentioned in Chapter 4. Throughout this chapter, the sample size (N) corresponds to 342 when referring to total annual electricity use and annual cooling electricity use (cooling both by fans and air conditioners). The sample size becomes 100 while analysing total annual electricity in relation to household characteristics (household size and number of air conditioners). The sample size also becomes 100 while analysing annual air-conditioning electricity use (cooling by air conditioners) in relation to household characteristics (household size and number of air conditioners) and it is 36 while analysing annual air-conditioning electricity use (cooling by air conditioners) in relation to household practices (air conditioning usage time and preferred set-point temperatures of air conditioners) as shown in Figure 7-1.

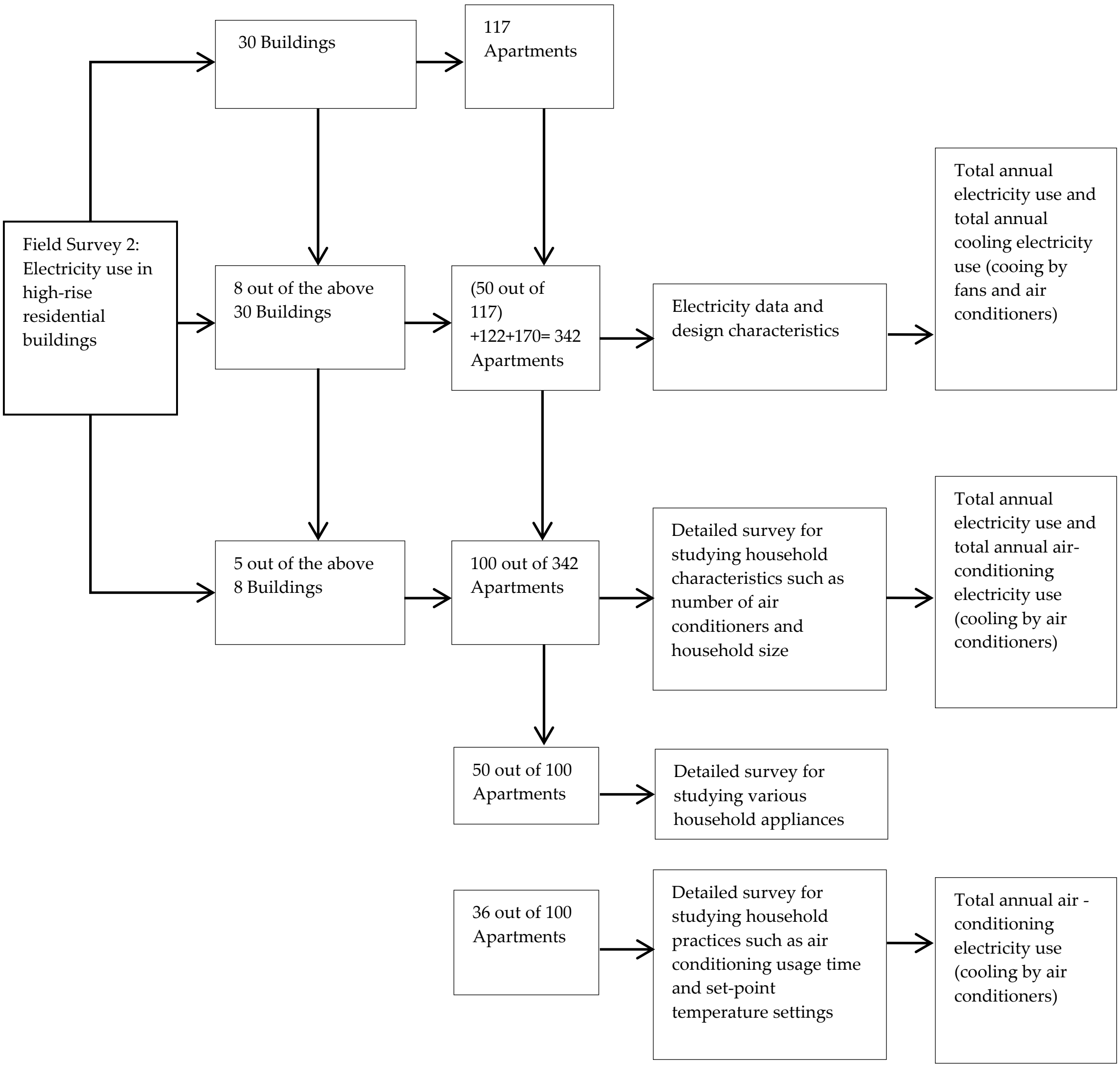


Figure 7-1: Data collection method and objective for electricity use

Descriptive statistics, correlations, linear regression analysis with SPSS (Version 20) were the different analysis methods used in this study. Descriptive statistics were used to summarise electricity use (total annual electricity and total annual cooling electricity) data by finding the mean and standard deviation. Pearson correlations were used to explore the strength of the relationship between two variables, i.e. total annual electricity use and a design characteristic. Pearson correlations give an indication of both the direction (positive or negative) and the strength of the relationship (Pallant 2011). A positive correlation indicates that as one variable increases, so does the other. A negative correlation indicates that as one variable increases, the other decreases.

A statistical technique of regression analysis may be used to relate a dependent variable with an independent variable (Lam et al. 1997). The objective of a linear regression analysis used in this study was to predict the independent variables (for instance apparent temperature, design characteristics and/or household characteristics) that affect the dependent variable that is the total annual electricity use/total annual cooling electricity use/total annual air-conditioning electricity use. In this study, to determine the effect of household characteristics in the model, the regression analysis was carried out in two steps in order to control for design characteristics. A linear regression analysis was used to analyse the influence of the following:

- Design characteristics on total annual electricity use;
- Household characteristics (household size and number of air conditioners) on total annual electricity use;
- Design characteristics on total annual cooling electricity use (cooling both by fans and air conditioners);
- Household characteristics (household size and number of air conditioners) on total annual air-conditioning electricity use (cooling by air conditioners); and
- Household practices (air conditioning usage time and set-point temperatures of air conditioners) on total annual air-conditioning electricity use (cooling by air conditioners).

7.3 Results

7.3.1 Design characteristics

The number of floors in the buildings surveyed varied from 8-20. While calculating the total annual electricity use, the apartments surveyed were on floors 2-20 as shown in Figure 7-2, whereas, while analysing total annual cooling electricity use, the apartments surveyed were on floors 3-20 as shown in Figure 7-3. In other words, no respondents on the second floor participated in the further study that analysed cooling electricity use.

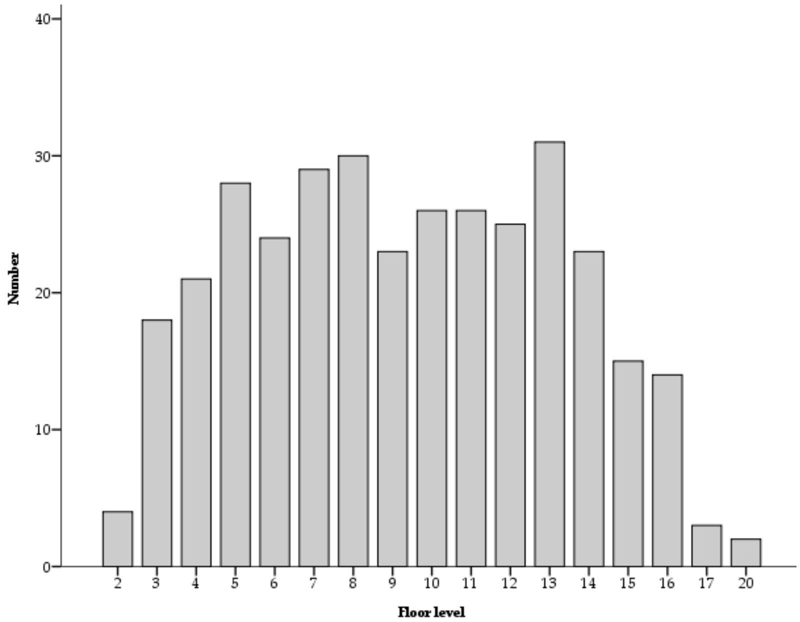


Figure 7-2: Number of apartments surveyed by floor levels (Sample size, N= 342)

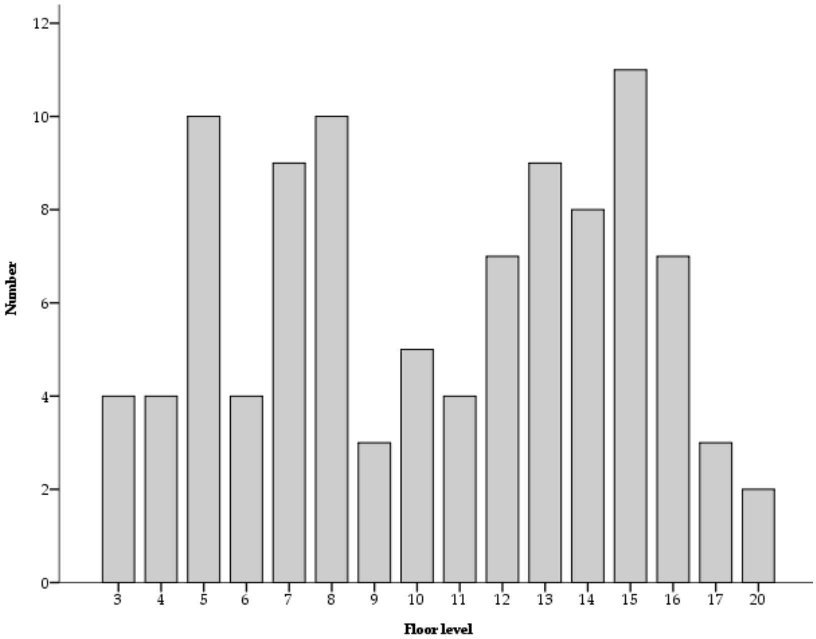


Figure 7-3: Number of apartments surveyed by floor levels (Sample size, N= 100)

Note that in this part of the study all the 342 apartments had three bedrooms and apartment size refers to the total area of the bedrooms, living room, dining room and kitchen in the apartments. The method for calculating effective canyon ratio was explained in Section 6.3.3.2. The gaps between the buildings in this part of the study varied from 2 metres to 6 metres.

Table 7-1 shows a summary of the descriptive statistics for each of the design characteristics with a sample size of 342 while Table 7-2 shows a summary of the descriptive statistics for each of the design characteristics with a sample size of 100. An examination of the data in Tables 7-1 and 7-2 show that the small sample size (N=100) reflects the same physical characteristics of the larger sample size (N=342), with the exception for effective canyon ratio. Therefore, the smaller sample (N=100) can be representative of the larger sample (N=342).

Table 7-1: Descriptive statistics of design characteristics of 342 apartments

Design characteristics	**Min**	**Max**	**Mean**	**SD**
Floor level	2	20	9	3.9
Apartment size	49 m^2	93 m^2	67 m^2	8.9
Area of master bedroom	10	21	14	1.5
Area of bedroom 2	9 m^2	16 m^2	12 m^2	1.3
Area of bedroom 3	8 m^2	14 m^2	10 m^2	1.0
Area of dining room	7 m^2	27 m^2	14 m^2	3.5
Area of living room	10 m^2	21m^2	13 m^2	2.2
Area of kitchen	4 m^2	10 m^2	7 m^2	1.5
Total window area	11 m^2	28 m^2	21 m^2	5.9
Total shading depth	0.1 m	1 m	0.6 m	0.2
Effective canyon ratio	0.1	34	5	5.2
Shape coefficient	0.1 m^{-1}	0.5 m^{-1}	0.4 m^{-1}	0.10

Table 7-2: Descriptive statistics of design characteristics of 100 apartments

Design characteristics	**Min**	**Max**	**Mean**	**SD**
Floor level	3	20	10	4.3
Apartment size	56 m^2	93 m^2	71 m^2	8.3
Area of master bedroom	10	21	14	1.8
Area of bedroom 2	9 m^2	16 m^2	12 m^2	1.3
Area of bedroom 3	8 m^2	14 m^2	10 m^2	0.9
Area of dining room	11 m^2	27 m^2	16 m^2	4.1
Area of living room	10 m^2	16 m^2	12 m^2	1.7
Area of kitchen	5 m^2	10 m^2	7 m^2	1.2
Total window area	12 m^2	28 m^2	24 m^2	5
Total shading depth	0.1 m	1 m	0.6 m	0.2
Effective canyon ratio	0.1	12	3	2.7
Shape coefficient	0.1 m^{-1}	0.5 m^{-1}	0.4 m^{-1}	0.10

7.3.2 Household characteristics and appliances

Household characteristics were surveyed in the second stage of the study. The mean household size of the 100 apartments was calculated as 4.4 persons, while the minimum and maximum were 1 and 9 persons per household respectively. The respondents had an average of 2.08 children per household.

All of the 100 apartments surveyed had air conditioners, but the number varied from a minimum of one to a maximum of four (mean=2). The air conditioners were mainly installed in the bedrooms of the apartments surveyed, particularly in the master bedroom. In 35% of the apartments surveyed, air conditioners were also installed in the other bedroom(s), but interestingly, only 8% of the apartments surveyed had air conditioners in the living rooms.

It is typical to have ceiling fans in the residential buildings of Dhaka and this study showed no deviation from the norm. There was at least one ceiling fan in each bedroom, living room and dining room, making a minimum of five ceiling fans in one apartment (as there were three bedrooms in the apartments). In some cases, when the rooms were big, there could be two ceiling fans in one room, making a maximum of up to 7 ceiling fans in one apartment. Not all apartments had table fans/pedestal fans and wall mountable fans; only 34 apartments had table fans while 17 apartments had wall mountable fans.

Out of these 100 apartments surveyed, the households of only 50 apartments were willing to express the number of various lighting fixtures and household appliances in their apartments. The descriptive statistics for the various lighting fixtures and household appliances in the 50 apartments are shown in Table 7-3.

Table 7-3: Descriptive statistics for household appliances in the 50 apartments

	Min	Max	Mean	SD
Energy efficient lights	0	10	4	1.5
Fluorescent lights	0	7	5	1.2
Incandescent lights	0	4	1	1.2
Spotlights	0	12	3	3.6
Kitchen exhaust fan	1	1	1	0.0
Blender	1	1	1	0.0
Fridge	1	2	1	0.3
Freezer	0	2	1	0.5
Microwave	0	1	1	0.1
Electric oven	0	1	0.3	0.5
Toaster	1	1	1	0
Blender	1	1	1	0
Juicer	0	1	0.3	0.5
Electric kettle	0	1	0.4	0.5
Rice cooker	0	1	1	0.5
Television	0	3	1	0.7
Radio	0	1	0.2	0.4
Washing machine	0	1	1	0.4
Water heater	0	4	2	1.0
Iron	1	2	1	0.3
Desktop computer	0	3	1	0.8
Laptop	0	3	1	0.7
Tablet	0	2	0.4	0.6
DVD player	0	2	1	0.5
Printer	0	1	1	0.5
Scanner	0	1	0.2	0.4
Router	0	1	0.2	0.4
Hair dryer	0	1	1	0.5
Hair straightener	0	1	1	0.5
Kitchen exhaust hood	0	1	1	0.5

7.3.3 Household practices

Household practices of the respondents were investigated in the second stage of the study, where 36 apartments among the 100 were revisited to collect data on these. Among various appliances generally used by the households in high-rise residential apartments, air conditioners, ceiling fans, table fans and wall fans were categorised as thermal-environmental control equipment, used for cooling purposes.

In order to analyse the total annual cooling electricity consumption of the households, data on the usage time of air conditioners and fans, set-point temperature ranges of (air conditioners) and speed settings of fans were collected. The mean air-conditioning usage time (in hours) of all the air conditioners was about 4.6 hours per day, whereas the minimum and maximum were 2 and 9 hours per day respectively (SD=2.25). The majority, 31% of the occupants, used air conditioning for 5 hours a day, as shown in Figure 7-4.

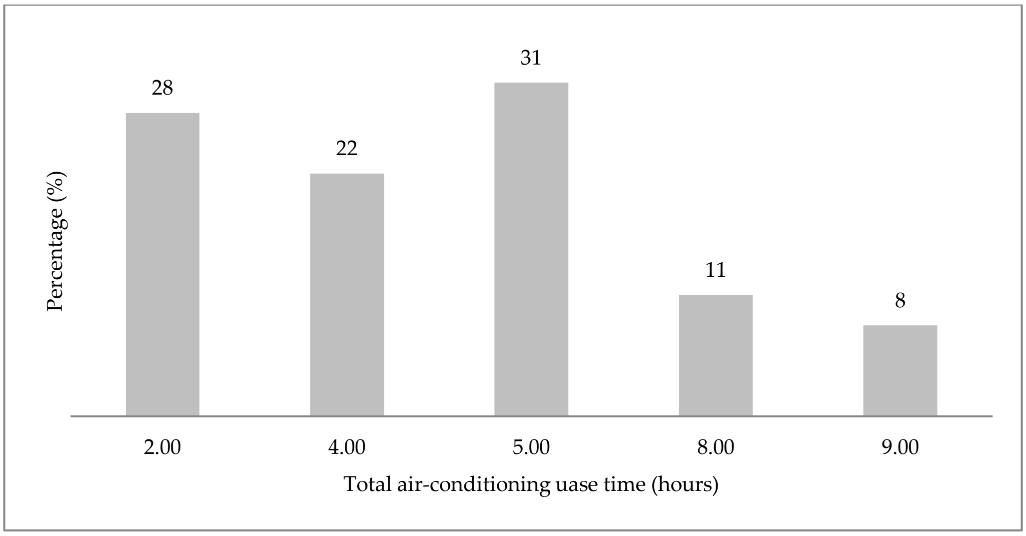


Figure 7-4: Air conditioning usage time in the 36 apartments

The set-point temperature ranges of air conditioners were categorised into 4 groups: Group1: 16-18°C, Group 2: 19-21°C, Group 3: 22-24°C and Group 4: 25-27°C. The study found that the mean set-point temperature ranges of the air conditioners in the households surveyed were between 22 and 24°C (SD=0.9) as shown in Figure 7-5.

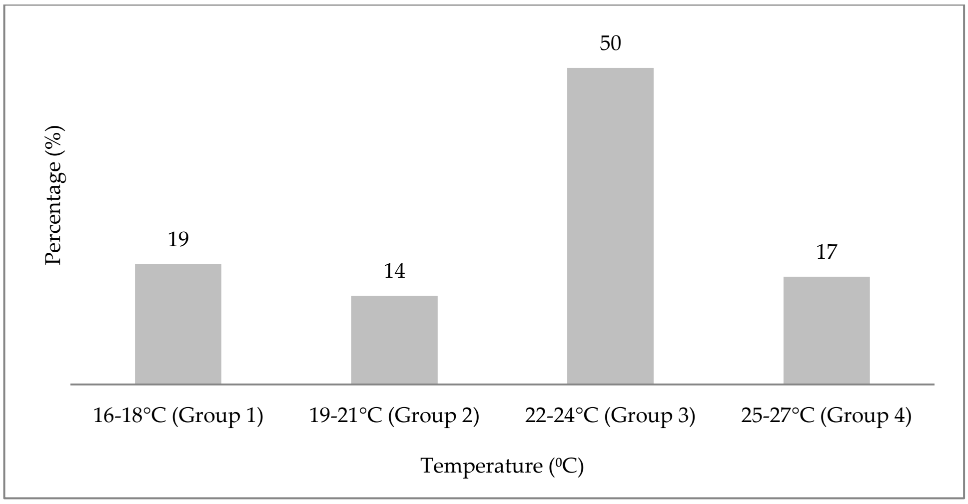


Figure 7-5: Set-point temperature ranges of air conditioners in the 36 apartments

Analysis on the usage patterns of fans shows that they were used whenever the households were present in the apartments. Among the five different speed settings of fans: very low, low, medium, high and very high, 21% of the households used high and 79% of them used very high settings.

7.3.4 Electricity use of apartments in high-rise residential buildings

7.3.4.1 Total annual electricity use of apartments in high-rise residential buildings

Based on the total annual electricity records of the 342 apartments, the mean total annual electricity use was 3776 kWh per apartment or 32 kWh/m^2 of usable floor area. The maximum, median and minimum monthly electricity use values are shown in Figure 7-6.

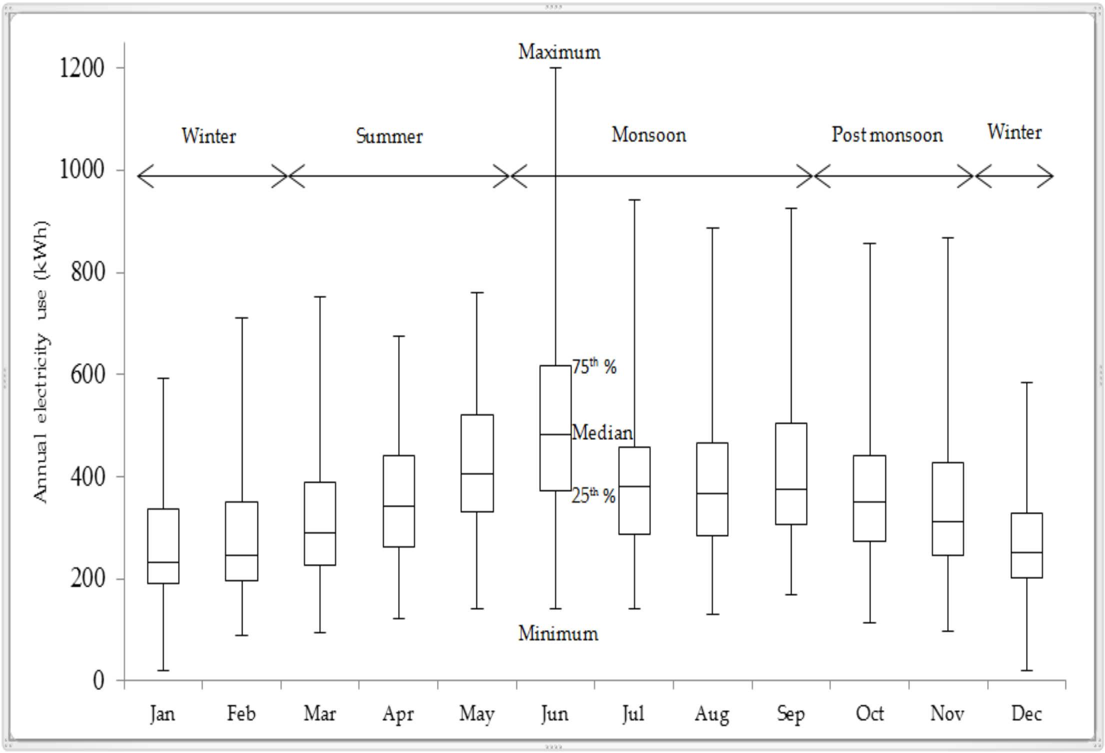


Figure 7-6: Box plot of monthly annual electricity use of the 342 apartments

This box and whisker plot of the monthly electricity use of these apartments clearly shows that electricity use in the apartments is related to the months of the year. According to the meteorological conditions, the climate of Dhaka can be divided into four seasons, pre-monsoon or summer (March–May), monsoon (June–September), post-monsoon (October–November) and winter (December–February). The mean minimum, mean maximum, mean temperatures, relative humidity, wind speed and vapour pressure data of Dhaka in 2012 are illustrated in Table 7-4.

Table 7-4: Monthly climate data of Dhaka for 2012

Seasons	Month	Temperature (°C) Mean Min	Temperature (°C) Mean Max	Mean Temp (°C)	Mean Relative Humidity (%)	Mean wind speed (m/s)	Mean water vapour pressure (hPa)
Pre-monsoon/ Summer	March	22	33	28	64	1	15
	April	24	34	29	71	1	17
	May	26	35	30	78	2	24
Monsoon	June	27	33	30	85	3	28
	July	27	32	30	85	2	33
	Aug	27	33	30	83	2	36
	Sept	27	33	30	84	2	35
Post-monsoon	Oct	24	32	28	78	2	34
	Nov	19	29	24	71	2	35
Winter	Dec	15	24	19	70	1	30
	Jan	14	24	19	69	1	21
	Feb	16	28	22	63	1	15

The monthly electricity use between May and September is significantly higher than other months in the year and the peak monthly electricity consumption occurred in June, which indicates the intensive use of air conditioners during monsoon when it is hot and very humid. This confirmed the study by Henning (2007) who showed that air conditioning is a common technical solution to the problems of increasing temperatures and includes both temperature and humidity control of the indoor air.

Studies have related increased electricity use to outdoor temperatures and humidity (Lundgren & Kjellstrom 2013). According to Valor et al. (2001), air temperature is found to be the most significant weather variable affecting electricity demand. Electricity demand is relatively insensitive to the air temperature interval of 15-21°C; however, below and above this interval, electricity consumption increases (Valor et al. 2001).

7.3.4.1.1 Relationship between apparent temperature and mean monthly electricity use

The relationship between apparent temperature and mean monthly electricity use was analysed whereby the apparent temperature was calculated by using Equation 7-1 and Ta is the monthly mean temperature. The correlation between the apparent temperature and the mean monthly electricity use of the apartments (N=342) as shown in Figure 7-7 illustrates that the mean monthly electricity use is strongly related to the apparent temperature (R^2 =0.87, p= 0.00).

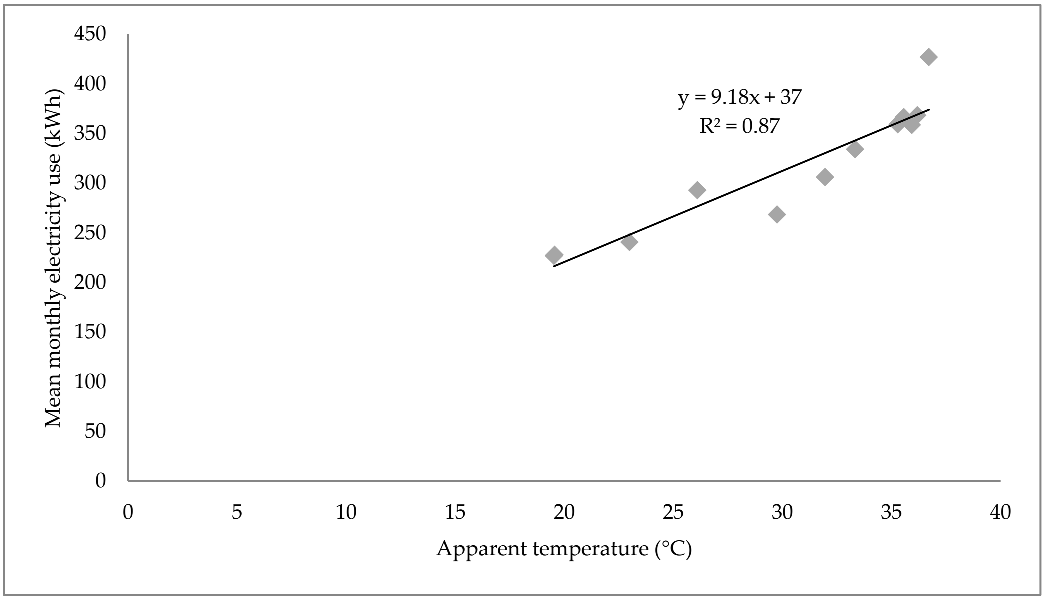


Figure 7-7: Correlation between apparent temperature and mean monthly electricity use in 342 apartments

7.3.4.1.2 Relationship between total annual electricity use, design characteristics and household characteristics

Relationship between design characteristics and total annual electricity use

Out of all the design characteristics studied in the 342 apartments (N= 342), apartment size, effective canyon ratio (H/W), total window area, total shading depth and shape coefficient appear to have correlations with total annual electricity use (kWh) as shown in Table 7-5.

Table 7-5: Relationship between design characteristics and total annual electricity use of 342 apartments

Design characteristics	Relationship	R^2	Significance (*p* value)
Floor level	-	0.00	0.61
Apartment size	+	0.11	0.00
Effective canyon ratio(H/W)	-	0.02	0.01
Total window area	+	0.07	0.00
Shading depth	+	0.02	0.01
Compactness (shape coefficient)	+	0.04	0.00

Regression model for prediction of total annual electricity use

Linear backward regression analysis was performed twice. The first analysis was to determine the six design characteristics that influenced total annual air electricity use, while the second was to analyse to what extent household characteristics, such as household size and number of air conditioners, explained the variations in total annual electricity use.

According to the first linear stepwise regression model, 12% (R^2=0.12, p= 0.00) of the variability in total annual electricity use was accounted for by design characteristics (N=342). In Table 7-6, the unstandardized coefficients of B and Standard Error of B, as well as the standardised coefficient Beta and the significance of the predictors are shown. Only apartment size and total window area were the statistically significant predictors of total annual electricity use, at the $p < 0.05$ level. The sign of the predictors in the regression model showed that total annual electricity use increased as both apartment size and total window area increased.

Table 7-6: Regression model for total annual electricity use (design characteristics as the independent variables)

Model 1: First regression analysis	Unstandardised Coefficients		Standardised Coefficients	Sig.
	B	Std. Error	Beta	
(Constant)	525	515	-	0.31
Apartment size	39	9	0.26	0.00
Total window area	29	14	0.13	0.04

The regression model predicting the total annual electricity use (without considering the influence of household characteristics) can be summarised with Equation 7-2 using the constant (C) and the B value in Table 7-6:

y = 525 + (39 x apartment size) + (29 x total window area)…… **[7-2]**

The unstandardised B coefficient indicates to what degree each predictor affects the outcome if the effects of the other predictors are held constant. It can be seen that "apartment size" was the most important predictor of the outcome according to the unstandardised B coefficient.

When both household size and number of air conditioners along with design characteristics were included in the regression analysis (N=100), the model represented 31% (R^2=0.31, p = 0.00) of the variability in total annual electricity use.

In Table 7-7, the unstandardised coefficients of B and Standard Error of B as well as the standardised coefficient Beta and the significance of the predictors are shown. Apartment size, effective canyon ratio and number of air conditioners were the statistically significant predictors of total annual electricity use at the $p < 0.05$ level, when the effect of both design and household characteristics were taken into consideration. The sign of the predictors in the regression model shows that total annual electricity use increased with increases in apartment size, effective canyon ratio and number of air conditioners.

Table 7-7: Regression model for total annual electricity use (design characteristics, household size and number of air conditioners as the independent variables)

Model 2: Second regression analysis	**Unstandardised Coefficients**		**Standardised Coefficients**	**Sig.**
	B	**Std. Error**	**Beta**	
(Constant)	-1833	1122	-	0.11
Apartment size	59	15	0.34	0.00
Effective canyon ratio	96	47	0.18	0.04
Household size	222	118	0.18	0.06
Number of air conditioners	500	191	0.24	0.01

The regression model predicting the total annual electricity use (considering the influence of both design and household characteristics) can be summarised with Equation 7-3 using the constant (C) and the B value in Table 7-7:

y = -1833 + (59 x apartment size) + (96 x effective canyon ratio) + (222 x household size) + (500 x number of air conditioners)…… **[7-3]**

In this model, it can be seen that “number of air conditioners” was the most important predictor of the outcome according to the unstandardised B coefficient.

7.3.4.2 Total annual cooling and air-conditioning electricity use

As the available electricity use data from the survey were total monthly consumption data, electricity use for cooling was disaggregated from the total electricity consumption using a method similar to the one conducted by Katipamula et al. (1992).

The cooling electricity use was estimated by using the following method. For each apartment, the lowest monthly electricity use was used as the baseline because it likely did not involve cooling (generally occurred during December to February). This becomes the baseline and therefore the rest of the electricity use for the other months was indicative of the cooling electricity used. The estimated total annual cooling electricity use for each apartment was thus calculated by adding the respective cooling electricity use of each month (found by subtracting the baseline energy from the monthly electricity use for the year). For example, Figure 7-8 shows an example of estimating monthly electricity use in an apartment where the baseline electricity was 597 kWh for the month of February as indicated by the shaded region. The unshaded regions in Figure 7-8 correspond to the monthly cooling electricity use of the apartment.

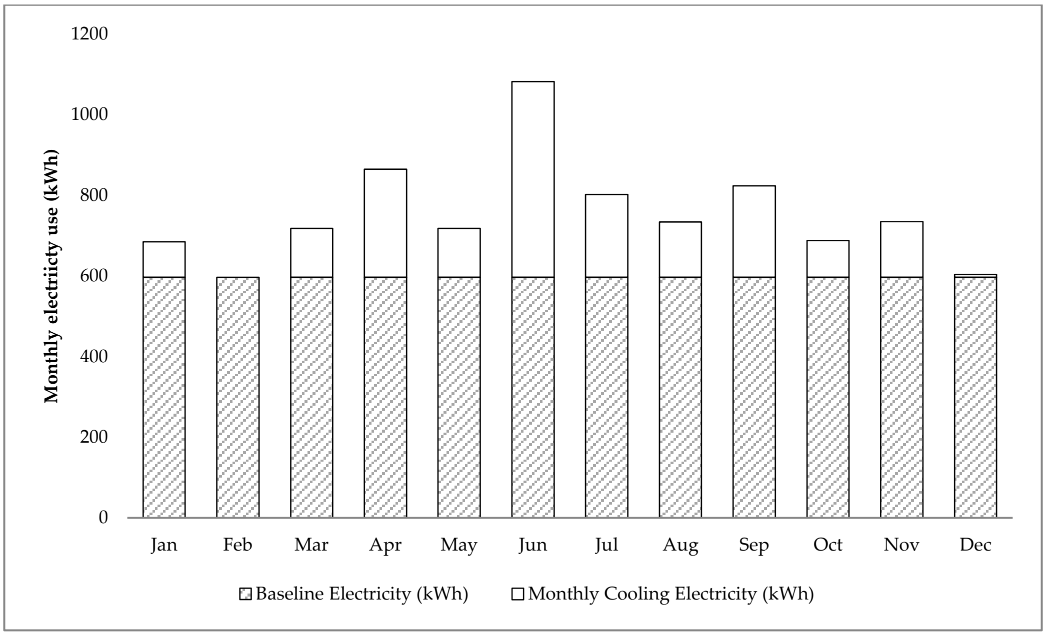


Figure 7-8: Method of estimating monthly cooling electricity use of an apartment based on the baseline electricity use

Based on this method of calculating the cooling electricity use, the mean annual cooling electricity use (cooling both by fans and air conditioners) of 342 apartments was estimated to be 1451 kWh, or about 38% of annual total electricity use, as shown in Table 7-8. The mean annual cooling electricity (cooling both by fans and air conditioners) for the usable floor area of 342 apartments was 12 kWh/m^2.

Table 7-8: Descriptive statistics for total annual cooling electricity use of 342 apartments

	Min	Max	Mean	SD
Total annual cooling electricity (kWh)	190	5051	1451	777
Total annual cooling electricity (kWh/square metres)	2	51	12	7

In order to find the mean annual air-conditioning electricity use (cooling by air conditioners) as shown in Table 7-9, the sample size was reduced to include only apartments that were known to have air conditioners (N= 100). The mean annual air-conditioning electricity use of the 100 apartments was estimated to be 1581 kWh, or about 36% of annual total electricity use (4357 kWh), as shown in Table 7-9. The mean annual air-conditioning electricity in the usable floor area of 100 apartments was 16 kWh/m^2.

Table 7-9: Descriptive statistics for total annual cooling electricity use of 100 apartments

	Min	Max	Mean	SD
Total annual cooling electricity (kWh)	454	3875	1581	725
Total annual cooling electricity (kWh/square metres)	3	33	13	6

7.3.4.2.1 Relationship between apparent temperature and mean monthly cooling electricity use

The relationship between apparent temperature and mean monthly cooling electricity use was analysed using Equation 7-1. The correlation between the apparent temperature and the mean monthly cooling electricity use of the apartments (N=342) as shown in Figure 7-9 illustrates that the mean monthly cooling electricity use is strongly related to the apparent temperature (R^2 =0.87, p= 0.00).

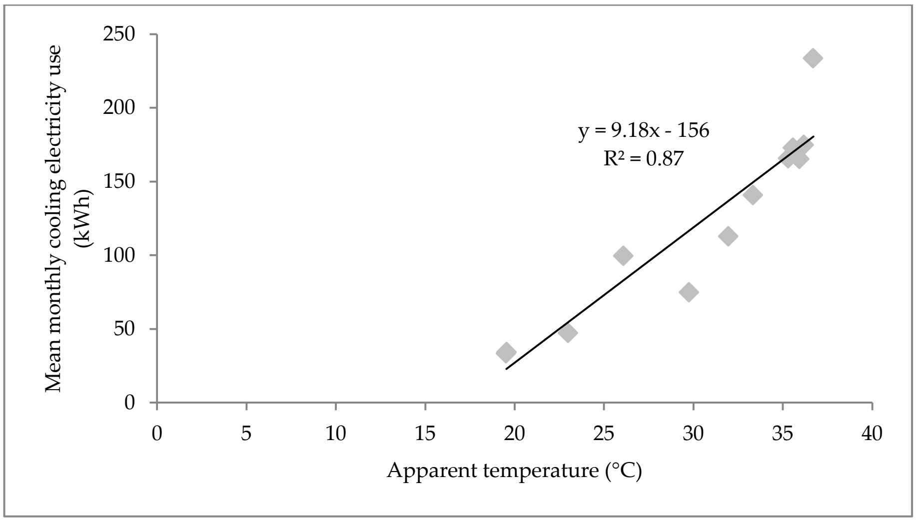


Figure 7-9: Correlation between apparent temperature and mean monthly cooling electricity use in 342 apartments

7.3.4.2.2 Relationship between total annual cooling electricity use, design characteristics and household characteristics

<u>*Relationships between design characteristics and total annual cooling electricity use*</u>

Out of all the design characteristics, floor level and apartment size appear to have correlations with estimated total annual cooling electricity use (kWh) as shown in Table 7-10. It should be noted that the correlation coefficient (R^2= 0.02) for both floor level and apartment size seems to be very low, however, they are significant (*p*= 0.02 and *p*= 0.01 respectively).

Table 7-10: Relationship between design characteristics and total annual cooling electricity use of 342 apartments

Design characteristics	Relationship	R^2	Significance (*p* value)
Floor level	-	0.02	0.02
Apartment size	+	0.02	0.01
Effective canyon ratio(H/W)	-	0.00	0.92
Total window area	+	0.00	0.57
Shading depth	-	0.00	0.84
Shape coefficient	+	0.00	0.31

Regression model for prediction of total annual cooling electricity use and total annual air-conditioning electricity use

As in the case of total annual electricity use, the linear backward regression analysis was performed twice. The first linear stepwise regression was performed using the six design characteristics to predict the independent variables of total annual cooling electricity use (N=342). According to the model, only 4% (R^2=0.04, *p*= 0.00) of the variability in total annual cooling electricity use was accounted for by design characteristics. In Table 7-11, the unstandardised coefficients of B and Standard Error of B, as well as the standardised coefficient Beta and the significance of the predictors are shown. Only floor level and apartment size, were the statistically significant predictors at the $p < 0.05$ level that influenced total annual cooling electricity use. The sign of the predictors in the regression model showed that total annual cooling electricity use decreased as floor level increased, and it decreased with a decrease in apartment size.

Table 7-11: Regression model for total annual cooling electricity use (design characteristics as the independent variables)

Model 1: First regression analysis	Unstandardised Coefficients		Standardised Coefficients	Sig.
	B	Std. Error	Beta	
(Constant)	861	332		0.10
Floor level	-25	11	-0.13	0.02
Apartment size	12	5	0.14	0.01

The regression model predicting the total annual cooling electricity use (without considering the influence of household characteristics) can be summarised with Equation 7-4 using the constant (C) and the B value in Table 7-11:

$$y = 861 - (25 \times \text{floor level}) + (12 \times \text{apartment size}) \ldots\ldots \textbf{[7-4]}$$

The unstandardised B coefficient indicates to what degree each predictor affects the outcome if the effects of the other predictors are held constant. It can be seen that "floor level" was the most important predictor of the outcome according to the unstandardised Beta coefficient.

When the design characteristics, household size and number of air conditioners were included in the second linear backward regression analysis (N=100), 8% (R^2=0.08, p = 0.02) of the variability in total annual air-conditioning electricity use (cooling by air conditioners) were indeed influenced by the design and household characteristics. It can, however, be noted that the value of R^2 in the two models, both for total annual cooling electricity use and total annual air-conditioning electricity use, is quite low (0.04 to 0.08). As the cooling electricity is based on estimated values, the precision of R^2 is low, but meaningful, because they are significant.

In Table 7-12, the unstandardised coefficients of B and Standard Error of B as well as the standardised coefficient Beta and the significance of the predictors are shown. Only apartment size and number of air conditioners were the statistically significant predictors at the $p < 0.05$ level that influenced total annual air-conditioning electricity use, when the effect of both design and household characteristics were taken into consideration. The sign of the predictors in the regression model showed that total annual air-conditioning electricity use increases with an increase in the apartment size and number of air conditioners.

Table 7-12: Regression model for total annual air-conditioning electricity use (design characteristics, household size and number of air conditioners as the independent variables)

Model 2: Second regression analysis	Unstandardised Coefficients		Standardised Coefficients	Sig.
	B	Std. Error	Beta	
(Constant)	100	616		0.87
Apartment size	17	9	0.19	0.06
Number of air conditioners	207	104	0.20	0.05

The regression model predicting the total annual air-conditioning electricity use (considering the influence of both design and household characteristics) can be summarised with Equation 7-5 using the constant (C) and the B value in Table 7-12:

y = 100+ (17 x apartment size) + (207x AC)…… **[7-5]**

The unstandardised B coefficient indicates to what degree each predictor affects the outcome if the effects of the other predictors are held constant. It can be seen that the number of air conditioners was the most important predictor of the outcome.

7.3.4.2.3 Relationship between total annual air-conditioning electricity use and household practices

Relationship between total annual air-conditioning electricity use and household practices

Out of the three household practices, namely, air-conditioning usage time, set-point temperature ranges of air conditioners and speed settings of fans, total annual air-conditioning electricity use (kWh) was found to be influenced by total air-conditioning usage time and set-point temperature ranges of air conditioners (Group1: 16-18°C, Group 2: 19-21°C, Group 3: 22-24°C and Group 4: 25-27°C) as shown in Table 7-13. Speed settings of fans did not significantly correlate with total annual air-conditioning electricity use.

Table 7-13: Correlations between household practices and total annual air-conditioning electricity use of 342 apartments

Household practices	Relationship	R^2	Significance (p value)
Total air-conditioning usage time	+	0.92	0.00
Set-point temperature ranges of air conditioners (groups 1-4)	+	0.17	0.01
Speed settings of fans	+	0.04	0.27

Regression model of household practices for prediction of total annual air-conditioning electricity use

As there was no correlation between total annual air-conditioning electricity use and the speed settings of fans, they were not investigated any further. Linear backward regression was then performed using the two household practices concerning air conditioners only (N=36): total air conditioning usage time and set-point temperature ranges of air conditioners (Group1: 16-18°C, Group 2: 19-21°C, Group 3: 22-24°C and Group 4: 25-27°C) to predict the variables that affected total annual air-conditioning electricity use. According to the model, 93% (R^2=0.93, p= 0.00) of the variability in total annual air-conditioning electricity use was accounted for by the household practices concerning air conditioners. In Table 7-14, the coefficients of B and Standard Error of B as well as the standardized coefficient Beta and the significance of the predictors are shown. Both of the predictors were statistically significant at the $p < 0.05$ level in influencing total annual air-conditioning electricity use. The sign of the predictors in the regression model showed that total annual air-conditioning electricity use, increased with lower set-point temperature ranges of air conditioners, and it increased with the increase in usage time of air conditioners.

Table 7-14: Regression model for total annual air-conditioning electricity use (household practices as the independent variables)

Model	Unstandardised Coefficients		Standardised Coefficients	Sig.
	B	Std. Error	Beta	
(Constant)	218	105		0.05
Set-point temperature ranges of air conditioners (groups 1-4)	-97	42	-0.12	0.03
Total air-conditioning usage time (hours)	358	19	1.02	0.00

The regression model predicting the total annual air-conditioning electricity use (considering the influence of household practices) can be summarised with Equation 7-6 using the constant (C) and the B value in Table 7-14:

y = 218 + (358x air conditioning usage time) - (97x set-point temperature ranges of air conditioners…… **[7-6]**

The non-standardised B coefficient indicates to what degree each predictor affects the outcome if the effects of the other predictors are held constant. It can be seen that "air conditioning usage time" was the most important predictor of the outcome according to the standardised Beta coefficient.

Air conditioning usage time had a higher non-standardised coefficient or beta value (B = 358, $p<0.05$) compared to set-point temperature ranges of air conditioners (B = 97, $p<0.05$). The beta value (B) for operational patterns of air conditioners was equal to +358. This meant that for a one-hour increase in air conditioning usage per apartment, there would be an increase of total annual air-conditioning electricity of 358 kWh. Similarly, the beta value for set-point temperature ranges of air conditioners was equal to -97. This meant that for each one set-point increase in temperature range (a difference of 3°C), there was a decrease of total annual air-conditioning electricity of 97 kWh.

As the value of R^2 is relatively high (0.93), the equation obtained in this regression analysis can be used to calculate fairly accurate savings in total annual air-conditioning electricity use for each of the predictors, air conditioning usage time and set-point temperature ranges of air conditioners. For example, if air conditioning usage was reduced from 9 hours to 2 hours, while the set-point temperature range was kept constant at group 3, (22-24 °C or the mean group), the total annual air-conditioning electricity use could be reduced from 3149 kWh to 643 kWh. The difference in total annual air-conditioning electricity use by reducing air conditioning usage by 7 hours (from 9 hours to 2 hours) was 2506 kWh and this difference resulted in a saving of 80% in total annual air-conditioning electricity use. In other words, for each hour reduction in air conditioning usage time, 11% (80%/7) air-conditioning electricity use could be saved annually. Similarly, if the set-point temperature ranges were changed from group 1 (16-18 °C) to group 4 (25-27 °C), while the air conditioning usage was kept constant at 5 hours (the mean air conditioning usage), the total annual air-conditioning electricity use could be reduced from 1911kWh to 1620 kWh. This showed a difference of 291kWh or 15%

savings in total annual air-conditioning electricity use. In other words, by increasing the set-point temperature ranges of air conditioners by one degree, 2% total annual air-conditioning electricity could be saved annually. Similar results have been found by Tzivanidis et al. (2011) for typical multi-storey buildings in Athens. However, their study does not clarify whether the buildings were residential.

7.4 Discussion

7.4.1 Relationship between apparent temperature and electricity use

Correlation of apparent temperature with both mean monthly electricity use and mean monthly cooling electricity use of the apartments illustrated that both mean monthly electricity use and mean monthly cooling electricity use is strongly related to apparent temperature. This explains why monthly electricity use between May and September was significantly higher than other months in the year, with the peak occurring in June, indicating the intensive use of air conditioners during monsoon as a result of the discomfort caused by the combined effects of air temperature, relative humidity and wind speed, in other words, the apparent temperature.

7.4.2 Regression analysis for total annual electricity use

In the regression analysis for total annual electricity use and the design characteristics (N=342) with design characteristics as the independent variables, apartment size and total window area were found to be the only two statistically design characteristics that affected total annual electricity use. This finding is quite different to the findings of Touchie et al. (2013), where annual electricity use was correlated with fenestration ratio, but not with apartment size. The building characteristics investigated by Touchie et al. (2013) included building height, size, vintage, fenestration ratio, glazing type, thermal conductance of glazing and mechanical system details and occupancy type.

The sign of the predictors in the regression model in this study shows that total annual electricity use increased as both apartment size and total window area increased. The increase in total annual electricity with an increase apartment size could perhaps be attributed to the fact that an increase in apartment size is indicative of increase in household size and the number of household appliances in the apartment. A correlation between apartment size, household size and number of appliances in the 50 apartments surveyed showed that apartment size is significantly correlated with the number of household appliances (R^2 =0.75, p= 0.00), but not with the household size. This suggests that if the apartment size increases, the number of household appliances also increases.

Total annual electricity use increased with an increase in the total area of the windows. This could be attributed to the heat gain through the glazing surface. In the case of hot-humid climates like Dhaka, where windows are considered important to provide air exchange for thermal comfort, decreasing the areas of windows to reduce the total annual electricity use would conflict with the requirement to provide windows for ventilation. As windows are inevitable in hot-humid climates like Dhaka, shading strategies may provide an answer to this conflicting issue, as it was seen that total annual cooling, electricity use had a positive correlation, though not significant, with shading depth, meaning that total annual cooling electricity use decreases with an increase in in the shading depth. However, it must also be pointed out total annual electricity had a significant positive correlation with shading depth, meaning that total annual electricity use increases with an increase in the shading depth. This could be attributed to the fact that an increase in the shading depth would lower the admittance of daylight and as a consequence, dependency on artificial lighting would increase, resulting in an increase in total annual electricity use.

It thus seems that the design characteristics taken as the only dependent variables on their own, are not able to generate a meaningful analysis, as total annual electricity, as the name suggests, is in fact dependent on a lot of other variables such as all the household appliances and lighting fixtures (show in Table 7-3) and usage time of these, which have not been included in this analysis due to unavailability of data.

In order to obtain a more accurate picture of the analysis on total annual electricity use, household size and number of air conditioners, the only known household characteristics, were added as the dependent variables along with design characteristics.

When both household size and number of air conditioners were included in the regression analysis along with the design characteristics (N=100), effective canyon ratio, household size and the number of air conditioners in addition to apartment size was found to affect total annual electricity use. However, window area was no longer a predictor even though it was one in the first instance, with design characteristics as the independent variables.

The correlation analysis between total annual electricity use and effective canyon ratio (H/W) shows a negative correlation, meaning that electricity use decreases as effective canyon ratio increases. This can be explained as narrow streets and high buildings create a larger shaded area in the urban canyon. Annual electricity use decreases as the shadowing effects lead to a lower temperature during the day and a consequently lowering cooling electricity use. When the regression analysis is done using only the design characteristics (N=342), the coefficient for effective canyon ratio was negative even though it was eliminated as a predictor. Apartment size and window area became the predictors of annual electricity use.

When household characteristics such as household size and number of air conditioners were included in the regression analysis for annual electricity use (N=100), together with the design characteristics, the coefficient for canyon ratio became positive and a predictor. It can thus be concluded that the influence of household size and number of air conditioners is strong, as after their inclusion into the regression analysis, an increase in effective canyon ratio results in an increase of total annual electricity use. Household size or the number of persons in an apartment is crucial because the anthropogenic heat released is a potential heat source for an apartment (Oke 1978). This heat released inside the apartments can be a by-product of activities (cooking, lighting, electrical appliances, etc.) and it includes the metabolic releases of the occupants inside the apartment. It can be concluded that an increase in household size would increase the anthropogenic heat released inside the apartment. In order to dissipate this heat from the apartment, the dependence on artificial cooling such as air conditioners is increasing. The need for natural ventilation or air exchange also increases with the onset of household size. As natural ventilation is highly influenced by the layout of building, spacing between and height of the surrounding buildings, highly dense areas would affect the potential for natural ventilation. When natural ventilation cannot be achieved, the likelihood of using air conditioners increases and this in turn increases the total annual electricity use.

7.4.3 Regression analysis for total annual cooling and air-conditioning electricity use

In the regression analysis for total annual cooling electricity use and the design characteristics (N=342), the cooling electricity represents both cooling by fans and air conditioners. Owing to data availability, it could not be ascertained which of the 342 apartments had air conditioners and which depended only on cooling by fans. In this analysis, it was found that floor level and apartment size were the only two statistically significant design characteristics that affected total annual cooling electricity use. This result is consistent with the findings of Yun and Steemers (2011) where cooling energy was significantly related with apartment size out of the other building characteristics such as apartment size, number of windows, year of construction and housing type. It must be noted not the influence of floor level on cooling electricity use was not investigated by Yun and Steemers (2011).

The sign of the predictors in the regression model in this study shows that total annual cooling electricity use increased as the apartment size increased and it decreased as floor level increased. This suggests that apartments on upper levels consumed less cooling electricity than those on lower floors. This could be due to the fact that the apartments on higher floors had better natural ventilation (it was shown in Section 6.3.5.3.1 that the respondents' satisfaction with perceived natural ventilation increased with an increase in floor level) and so the dependency on air conditioners was probably low.

When both household size and number of air conditioners were included in the regression analysis, along with the design characteristics (N=100), only apartment size and number of air conditioners were the statistically significant predictors that influenced total annual air-conditioning electricity use, showing that total annual air-conditioning electricity use increased with an increase in the apartment size and number of air conditioners. This implies that once the household characteristics, mainly the numbers of air conditioners, are included in the regression analysis, floor level no longer has an influence on total annual air-conditioning electricity use.

In addition to the influence of household characteristics, when household practices such as set-point temperature ranges and air conditioning usage time were included in the regression analysis (N=36), both set-point temperature ranges and air conditioning usage time contributed significantly to total annual air-conditioning electricity use. It was found that for each hour reduction in air conditioning usage time, 11% total annual air-conditioning electricity use could be saved annually, and by increasing the set-point temperature ranges of air conditioners by one degree, 2% total annual air-conditioning electricity could be saved annually.

7.5 Chapter Summary

Certain combinations of the design characteristics of high-rise residential buildings can have an influence on the total annual electricity use, total annual cooling electricity use and total annual air-conditioning electricity use; however, they were only able to explain a relatively small percentage of total annual cooling electricity use and total annual air-conditioning electricity use.

When the independent variables were design characteristics, apartment size and window area explain 12% of the variance in total annual electricity use. When household size and number of air conditioners were included as the independent variables for the regression analysis of total annual electricity use, apartment size, effective canyon ratio, household size and number of air conditioners all became the predictors. The results showed that apartment size, effective canyon ratio, household size and number of air conditioners together explain 31% of the variance in total annual electricity use.

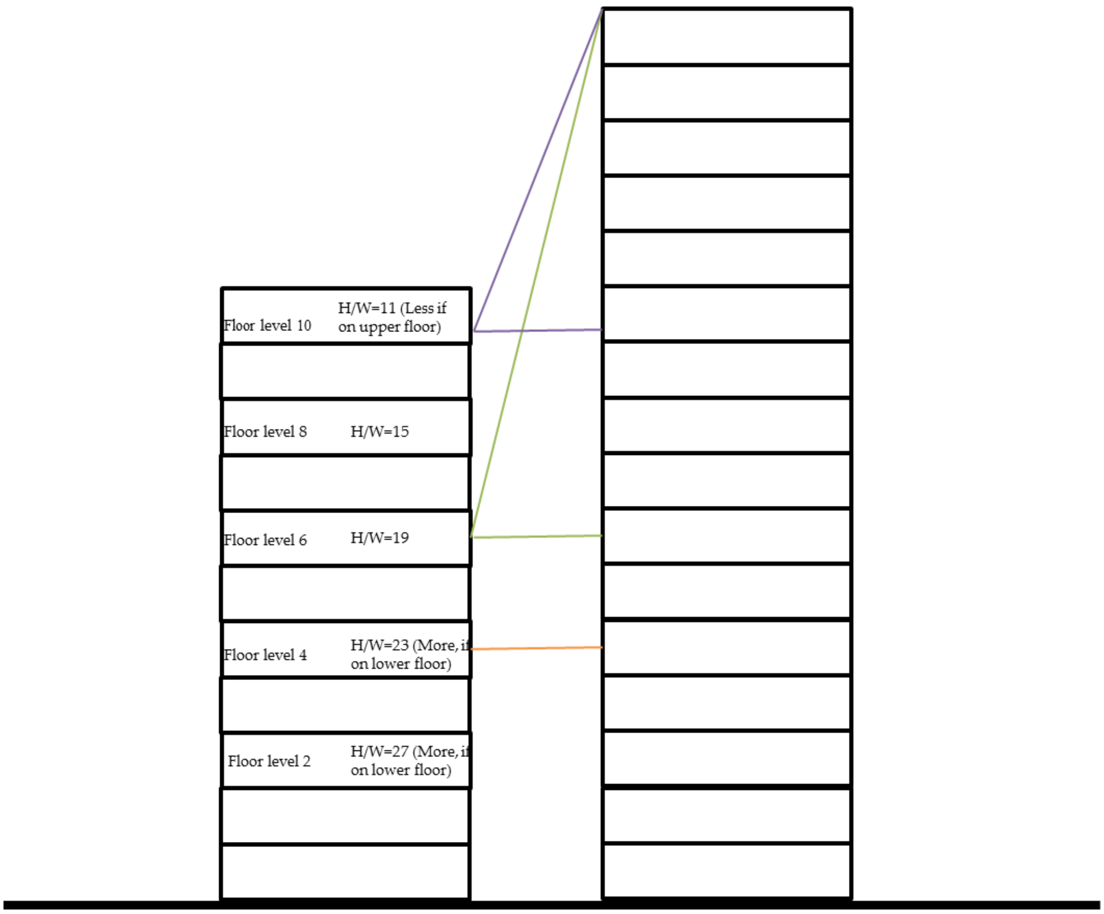


Figure 7-10: Figure explaining the literal meaning of different values of effective canyon ratio

An increase in effective canyon ratio literally means a lower floor level as illustrated in Figure 7-10. Hence, total annual electricity in an increased effective canyon ratio (or lower floors) with larger floor area, larger household size and more air conditioners would consequently be more. Thus, in order to have reduced total annual electricity use, in an increased effective canyon ratio (on lower floors), the apartment size needs to be small.

Equation 7-3 has been used to show the total annual electricity use for increased effective canyon ratio (or lower floors) and different values of apartment size. While calculating the total annual electricity use for various cases, the effects of the other predictors (effective canyon ratio, household size and number of air conditioners) in Equation 7-3 were kept constant. It must be noted that the values of the parameters used in Equation 7-3 are within the range of data collected from the samples.

Table 7-15: Total annual electricity use for increased effective canyon ratio (or lower floors) for various cases

Floor level	**Apartment size (square metres)**	**Effective canyon ratio**	**Household size**	**Number of air conditioners**	**Total annual electricity use (kWh)***
2	84	27	4	2	7559
2	76	27	4	2	7070
3	84	25	4	2	7370
3	76	25	4	2	6881
4	84	23	4	2	7181
4	76	23	4	2	6692
5	84	21	4	2	6692
5	76	21	4	2	6503

* Calculated based on Equation 7-3

Table 7-15 shows that when the value of apartment size is decreased in each case for the lower floor levels (2, 3, 4 and 5) while keeping the effects of the other predictors (household size and number of air conditioners) constant, the total annual electricity use decreases.

When the independent variables were design characteristics, apartment size and floor level explain only 4% of the variance in total annual cooling electricity use. The sign of these predictors in the regression model indicated that a decrease in floor level would increase total annual cooling electricity use, whereas on the contrary, a decrease in apartment size would decrease the total annual cooling electricity use. This means that lower floor levels with larger apartment size use more total annual cooling electricity compared to higher floor levels with the same apartment size.

This indicates that if an apartment is large, it needs to be on a higher level of the building to reduce the total annual cooling electricity use, similar to the case above.

The above can be illustrated by using different values of floor level and apartment size in Equation 7-4 to calculate the total annual cooling electricity use. It must be noted that the floor level and corresponding apartment size and effective canyon ratio have been taken from the actual data.

Table 7-16: Total annual cooling electricity use for different floor levels and apartment sizes for various cases

Floor level	**Apartment size (square metres)**	**Total annual cooling electricity use (kWh)***
2	90	1891
2	57	1495
3	90	1865
3	49	1379
4	90	1840
4	49	1354
5	90	1815
5	49	1329
6	90	1790
6	49	1304
17	90	1519
17	57	1120
20	90	1441
20	57	1045

* Calculated based on Equation 7-4

It is evident from Table 7-16 that larger size apartments (for instance, 90 square metres) on lower floor levels (second floor) use more total annual electricity compared to apartments of the same size (90 square metres) on higher floor levels (twentieth floor). For instance, apartments of 90 square metres use more total annual electricity on the lower floor levels (as shown by the shaded regions for floors 2 to 6), compared to apartments of the same size (90 square metres) on higher floor levels (as shown by the shaded region for the seventeenth and twentieth floor). Table 7-16 also illustrates that the total annual cooling electricity of larger size apartments is more than that of smaller size apartments on the same floor levels. For instance, an apartment on the second floor with an area of 90 square metres uses more electricity (1891 kWh) compared to an apartment of 57 square metres on the same floor level (1495 kWh).

When household size and number of air conditioners were included as the independent variables for the regression analysis of total annual air-conditioning electricity use, apartment size and number of air conditioners were the predictors. The results showed that apartment size and number of air conditioners together explain only 8% of the variance in total annual air-conditioning electricity use. The sign of the predictors in the regression model showed that total annual air-conditioning electricity use increased with an increase in both apartment size and number of air conditioners.

In addition to the influence of design characteristics, household practices regarding set-point temperatures and usage time of air conditioners were also seen to have an impact on total annual air-conditioning electricity use. As less electricity is used when the set-point temperature ranges of air conditioners is high (for instance 25-27 °C), if very low temperature ranges (16-18°C) are preferred as the set-point temperature ranges of air conditioners, the usage time should be less; whereas, at high-temperature ranges, air conditioning usage can be longer. Hence, it is important to adjust the set-point temperature ranges and air conditioning usage in such a way that maximum savings in total annual air-conditioning electricity are possible. The findings of this chapter also highlight that the influence of apparent temperature and household practices on electricity use is significantly higher than the design characteristics. These results are consistent with the findings of Yun and Steemers (2011) on residential buildings, where they assert that the design characteristics rank low in terms of their influence on cooling energy, and climate is the single most significant parameter, followed by behavioural issues and household income.

Section III: Recommendations and Conclusion

8 Strategies for Socially and Environmentally Sustainable Practices

8.1 Introduction

The final outcome of this thesis is the development of strategies for socially and environmentally sustainable practices based on the findings from the field studies as presented in Chapters 5, 6 and 7. Chapter 5 addresses the second research question: what are the views of the stakeholders in achieving socially and environmentally sustainable practices for high-rise residential buildings? Chapter 6 addresses the third research question: what are the current conditions, problems, constraints and achievements of the high-rise residential buildings in Dhaka, Bangladesh? While Chapter 7 addresses the fourth research question: what are the factors that affect electricity use in high-rise residential buildings? Based on the findings from addressing these research questions, this chapter discusses the answer to the fifth and final research question: what are the strategies for social and environmentally sustainable practices for high-rise residential buildings in Dhaka and what are the potential implications of applying these strategies?

8.2 Method: Critical Review Process

A draft for the strategies for socially and environmentally sustainable practices for high rise residential buildings in Dhaka was first formulated based on the findings from the chapters mentioned above (See Appendix F). These strategies were based on the following:

- The perspectives of the stakeholders involved in the construction industry (Chapter 5);
- The findings from the survey of the high-rise residential buildings and the needs and satisfactions of the respondents (Chapter 6); and
- The electricity use analysis of the high-rise residential buildings (Chapter 7).

Once the draft had been prepared, a review process was carried out by presenting it to the 21 stakeholders (See Table 8-1) from the initial 124 who had taken part in the stakeholder questionnaire survey. Due to a great difficulty in arranging a focus group discussion with all 21 stakeholders, the discussion took the form of a one-on-one meeting. The feedback and comments from the 21 stakeholders were obtained through verbal and/or written comments via face-to-face communication. The stakeholders appreciated the comprehensive nature of strategies and found them useful in regards to addressing social and environmental issues that are of grave concern in Dhaka.

Table 8-1: Distribution of stakeholders in the review process

Profession	**N**
Architect	9
Planner	3
Real estate developer	2
Civil engineer	2
Environmental engineer	2
Policy maker	3

8.3 Results: Additional Strategies

The feedback from the 21 stakeholders was analysed and the comments were incorporated when relevant, leading to changes to the draft. The strategies were modified by adding some more criteria to the social and environmental issues based on the recommendations by the stakeholders. These additional strategies have been grouped and are provided below. The final strategies will be presented later.

8.3.1 Social issues

8.3.1.1 Culture and heritage

1. In order to provide a design that responds to the urban context, the following must be considered:
    - The urban design should be compatible with the local cultural values;
    - A podium should be designed to reduce the vertical scale of the entire building to create a sense of a pedestrian scale at street level; and
    - A stepped building form can be used to relate to existing adjacent low-rise buildings.

8.3.1.2 Spatial design

1. The storage space can be located in the false ceiling slab. Service areas like toilets and kitchens can be located collectively for an increase in storage space in false ceiling slab and easy maintenance of plumbing.
2. In order to increase efficiency of space, the use of multi-functional furniture systems, especially in the smallest bedroom, can be adapted. The bedroom can be used as a family living room or as a study room by using wall beds that can be transformed into desks and shelving units.

8.3.1.3 Community safety and security

1. Burglar alarms should be deployed in all apartments of the buildings.

8.3.1.4 Maintenance plan

1. In order to ensure regular maintenance of all building services, features and measures, the following needs to be considered:
    - A monitoring unit needs to be set up that would conduct post occupancy evaluation of all the building services and user satisfaction; and
    - The service charge should be made transparent.
2. In order to manage the traffic in high-rises, the management staff in the buildings should be responsible for controlling the traffic in and out of the buildings.

8.3.1.5 Education and awareness

1. When apartment owners sign the document of flat ownership they should be informed/educated about water efficient fixtures and energy efficient lamps.

8.3.2 Environmental issues

8.3.2.1 Impacts on adjacent properties

1. In order to ensure buildings positively complement their existing context and enhance agreed aspirations for the future development of the area, the following must be considered:
    - The likely location, size and expected impact of future developments.

8.3.2.2 Construction practice

1. A monitoring unit needs to be set up by the relevant government authorities to oversee efficient management of fire safety in the buildings.

2. The building services should have an emergency response team managed by responsible fire wardens, security staff and management staff.

3. Fire protection measures need to incorporate an integrated fire safety system and an emergency management plan.

4. Regular inspections of fire-fighting facilities should be made mandatory.

5. High-rise residential buildings above 14 floors need to have helipads for evacuation in case of a major fire outbreak.

6. In order to ensure the building does not collapse during its design lifetime, the following need to be considered:

    - The building construction process should be monitored vigilantly by employing qualified and trained engineers;
    - The provisions of safety inspections of key structural elements by qualified persons after completion should be made;

- An active monitoring unit needs to be set up by the relevant governing authorities to ensure that all standards are met;
- Quality approach in structural design, details and specifications; and
- Commitment to high standards of construction management and building safety beyond statutory duties.

7. In order to ensure the building does not collapse during natural disasters, the design of buildings should include a multi-hazard approach that accounts for potential impacts of seismic forces, as well as all major hazards that the location is vulnerable to.

8.4 Results: Final Strategies

After all the adjustments were made to the draft strategies, the final strategies were compiled. These consist of 5 social issues with a total of 22 objectives and 49 strategies; and 9 environmental issues with a total of 23 objectives and 55 strategies.

8.4.1 Socially sustainable practices for high-rise residential buildings

The socially sustainable practices for high-rise residential buildings consist of the 5 social issues together with the objectives under each issue and the strategies under each underlying objective as shown in Figure 8-1.

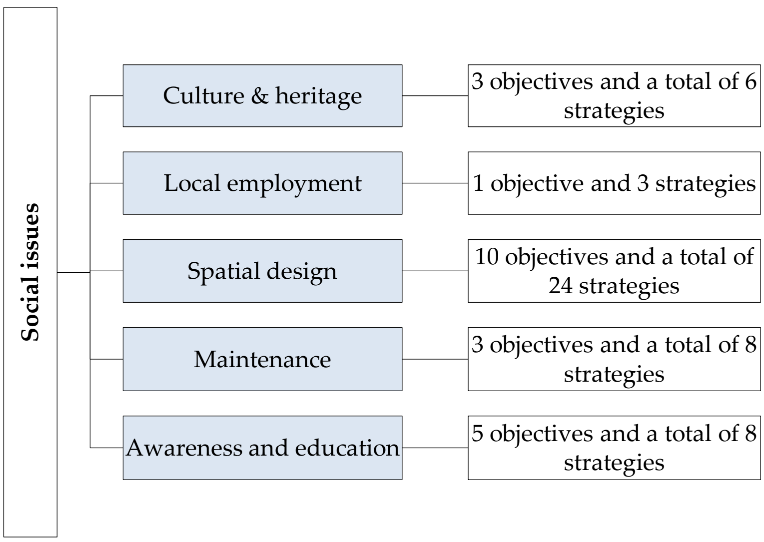


Figure 8-1: Socially sustainable practices for high-rise residential buildings

8.4.2 Environmentally sustainable practices for high-rise residential buildings

The environmentally sustainable practices for high-rise residential buildings consist of the 9 environmental issues together with the objectives under each issue and the strategies under each underlying objective as shown in Figure 8-2.

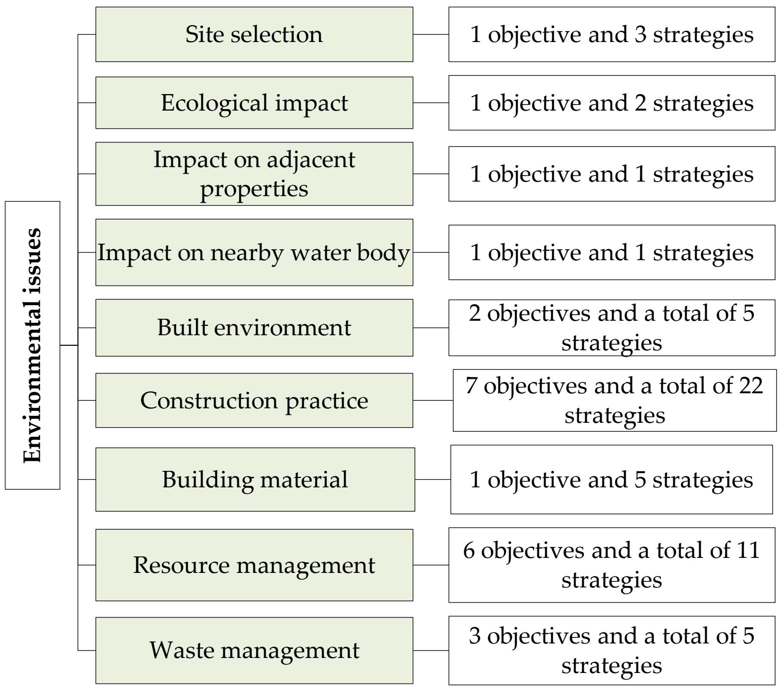


Figure 8-2: Environmentally sustainable practices for high-rise residential buildings

8.4.3 Overall socially and environmentally sustainable practices for high-rise residential buildings

In the following Sections (8.4.3.1 to 8.4.3.4), the 5 social issues and the 9 environmental issues together with the objectives under each issue as well as the strategies under each underlying objective are presented in the following order: planning, design, construction and building operation stages (Figure 8-3). The planning stage includes issues such as site selection, ecological impact, impact on adjacent properties and impact on nearby water bodies. The design stage includes issues on culture and heritage, local employment and spatial design and built environment. The construction stage includes issues on building construction and building materials, while the building operation stage includes issues of maintenance, resource management, waste management and awareness and education. A table in each section shows the survey and the chapter with the section number in this thesis from which the strategies were formulated.

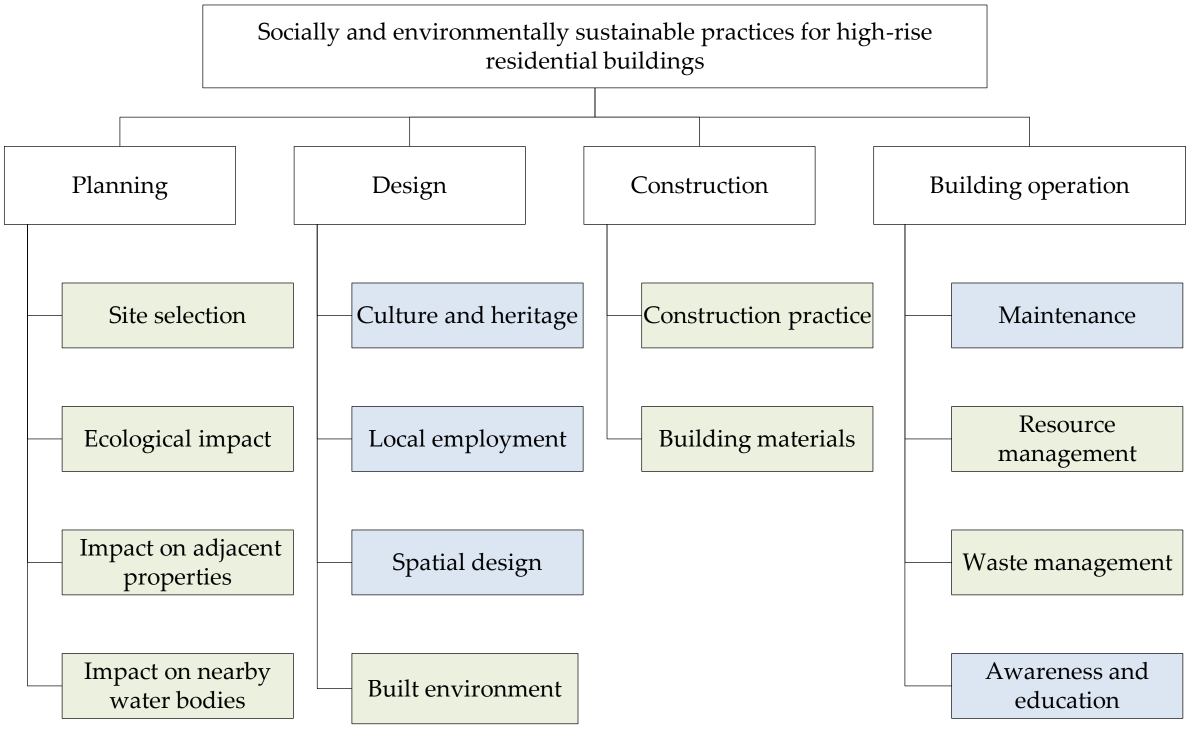


Figure 8-3: Socially and environmentally sustainable practices for high-rise residential buildings

8.4.3.1 Planning stage

8.4.3.1.1 Site selection

Table 8-2: Strategies on "Site selection"

Issue: Site selection	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.1
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.1
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.1

Objective 1: To ensure appropriate selection of land in terms of the environmental consequences

Strategy 1: Any new development should be preceded by flood risk assessments of the site.

Strategy 2: Any new development should be preceded by seismic assessments of the site.

Strategy 3: The agricultural or ecological value of the site should be conserved.

8.4.3.1.2 Ecological impact

Table 8-3: Strategies on "Ecological impact"

Issue: Ecological impact	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.2
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.2

Objective 1: To conserve and enhance the overall ecological quality of the site and its surroundings

Strategy 1: Any new development should be preceded by ecological risk assessments of the site.

Strategy 2: Damage to existing soil, water bodies and flora and fauna of the site and adjacent land due to construction process should be minimised.

8.4.3.1.3 Impact on adjacent properties

Table 8-4: Strategies on "Impact on adjacent properties"

Issue: Impact on adjacent properties	Study	Chapter	Section
	Objective 1		
Strategy 1	Critical review process: Presentation of draft to stakeholders	Chapter 8	8.3.2.1

Objective 1: To ensure that buildings respond positively to their existing context and to agreed aspirations for the future development of the area

Strategy 1: Any new development should be preceded by an urban context report that considers the likely location, size and expected impact of future developments.

8.4.3.1.4 Impact on nearby water bodies

Table 8-5: Strategies on "Impact on nearby water bodies"

Issue: Impact on nearby water bodies	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.5

Objective 1: To conserve the nearby water bodies

Strategy 1: Water contamination in nearby water bodies during the building operation should be minimised.

8.4.3.2 Design stage

8.4.3.2.1 Culture and heritage

Table 8-6: Strategies on "Culture and heritage"

Issue: Site selection	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.1
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.1
	Objective 2		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.1
	Objective 3		
Strategy 1	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.1.
Strategy 2	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.1
Strategy 3	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.1

Objective 1: To ensure that the buildings are culturally acceptable

Strategy 1: Local cultural values should be considered by respecting the formal and informal zone.

Strategy 2: Design of buildings should relate with the existing streetscape.

Objective 2: To ensure the conservation of heritage values

Strategy 1: The heritage value at the urban level should be maintained.

Objective 3: To ensure that the design responds to the urban context

Strategy 1: The urban design should be compatible with the local cultural values.

Strategy 2: A podium could be designed to reduce the scale of the building to create the impression of a pedestrian scale at street level.

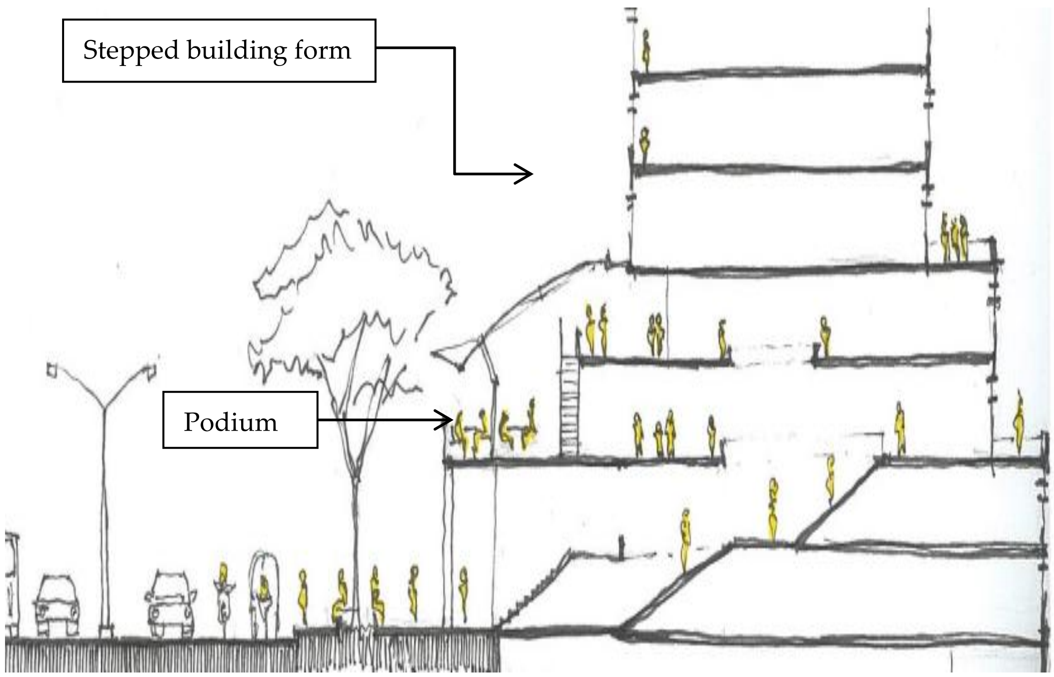


Figure 8-4: Conceptual section showing podium and stepped building form

Strategy 3: A stepped building form can be used to relate to existing adjacent low-rise buildings.

8.4.3.2.2 Local employment

Table 8-7: Strategies on "local employment"

Issue: Local people and employment	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.5
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.5
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.5

Objective 1: To ensure local employment in building construction

Strategy 1: Experienced and local design team should be consulted for the design of the buildings.

Strategy 2: Experienced and local contractors should be consulted for the construction of the buildings.

Strategy 3: Experienced and local construction workers should be employed for the construction of the buildings.

8.4.3.2.3 Spatial design

Table 8-8: Strategies on "Spatial design"

Issue: Spatial design	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Objective 2		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.5.2.3
Strategy 3	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.2
Strategy 4	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.5.2.3
Strategy 5	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.5.2.3
Strategy 6	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.5.2.4
Strategy 7	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.2
	Objective 3		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.2
	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.5.2.2
	Objective 4		

Issue: Spatial design	Study	Chapter	Section
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.7
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.3.3.1
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.7
Strategy 4	Household questionnaire survey	Chapter 6	6.3.7
Objective 5			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
Strategy 2	Household questionnaire survey	Chapter 6	6.3.5.2.1
Objective 6			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.5.2, 6.3.3.6 & 6.3.7
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
	Household questionnaire survey	Chapter 6	6.3.3.6 & 6.3.7
Objective 7			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
Objective 8			
Strategy 1	Household questionnaire survey	Chapter 6	6.3.2.5 & 6.3.5.1
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.2
Objective 9			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.3
	Household questionnaire survey	Chapter 6	6.3.2.4 & 6.3.7
Strategy 2	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.3
Objective 10			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.3

<u>Objective 1: To ensure that the design team and involved groups are aware of the occupants' spatial needs and priorities</u>

Strategy 1: The users (building occupants) should interact with the design team during the concept and design development phase to ensure that their spatial needs are fulfilled.

Strategy 2: Interdisciplinary work among the involved groups should take place from the beginning of the design process to address the spatial needs of the occupants.

<u>Objective 2: To promote the functionality, usability, flexibility and efficiency of the apartments</u>

Strategy 1: The spaces in the apartments should be planned for maximum flexibility.

Strategy 2: For apartments with three bedrooms, the size of the first bedroom (master bedroom) should be larger than the size of the second bedroom, which should not be less than 11.7 (≈ 12) square metres, while the size of third bedroom should not be less than 11.1 (≈ 11) square metres.

Strategy 3: The use of multi-functional furniture systems, especially in the smallest bedroom can be adapted. The bedroom can be used as a family living room or as a study room by using wall beds that can be transformed into sofas.

Figure 8-5: Multiunit furniture system showing a wall bed transformed into a sofa

Strategy 4: The size of the living room should not be less than 12.7 (≈ 13) square metres.

Strategy 5: The size of the dining room should not be less than 13.2 (≈ 13) square metres.

Strategy 6: Each apartment must be provided with a minimum of 1.5 square metres of storage room.

Strategy 7: Service areas such as toilets and kitchens can be located collectively to provide storage space in the false slabs of the ceilings.

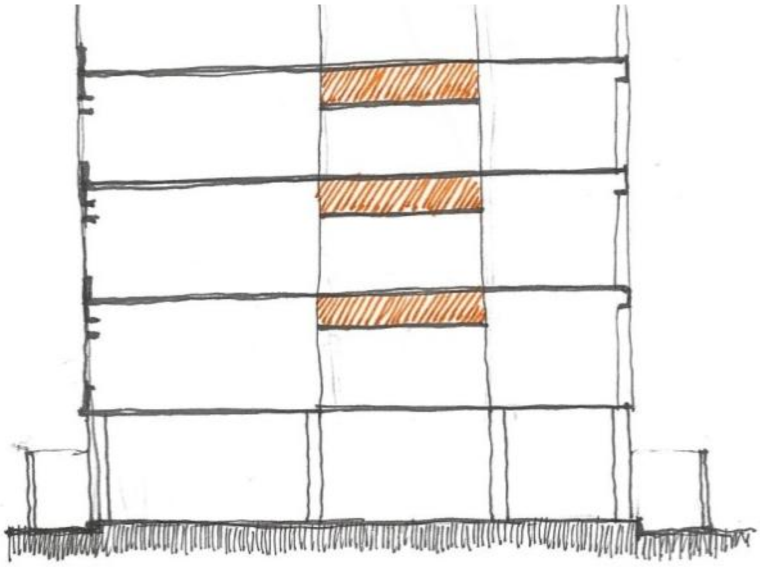


Figure 8-6: Conceptual section showing false slabs for storage in collectively located service areas

Objective 3: To ensure playing space for children, space for social interaction and greenery

Strategy 1: The open space in front of a building should be at least 50% of the entire site.

Objective 4: To enhance social interaction amongst the building occupants

Strategy 1: The rooftop can be used as spaces for interaction and outdoor recreation areas.

Strategy 2: The lobby needs to be well lit and naturally ventilated to enhance interaction amongst the occupants.

Strategy 3: Well-designed interactive community spaces, in addition to the community halls, must be provided.

Strategy 4: Consideration should be given to gyms with indoor game facilities.

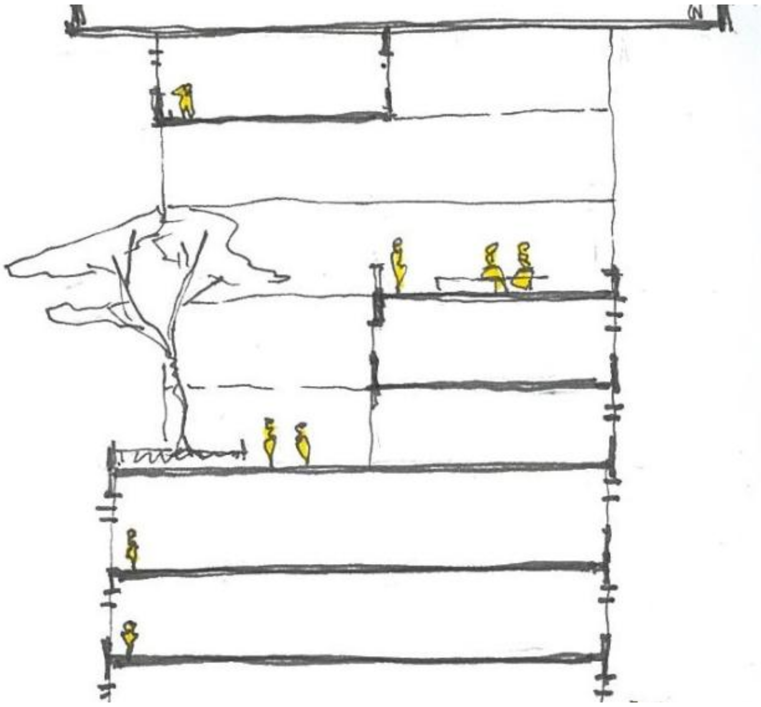


Figure 8-7: Conceptual section showing interactive community spaces

<u>Objective 5: To give due attention to visual privacy, including views to and from windows and balconies in the high-rise residential building from buildings immediately next</u>

Strategy 1: Impacts on visual privacy from adjacent buildings need to be minimised.

Strategy 2: The setback distance between adjacent buildings on different sites needs to increase to at least 7.3 metres (≈ 7) (from the current practice of 6 metres) where windows and balconies are present. In case of two buildings on one site, the setback distance should be at least 2.5 metres (the current practice) only if there is no window and balcony. If there are balconies and windows, they should be either diagonally located without facing each other, or the sill and lintel height of the windows of the two buildings should be different from each other.

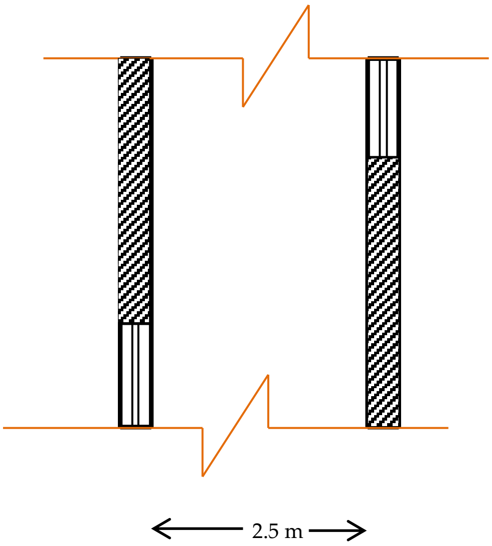


Figure 8-8: Conceptual plan showing diagonal location of windows

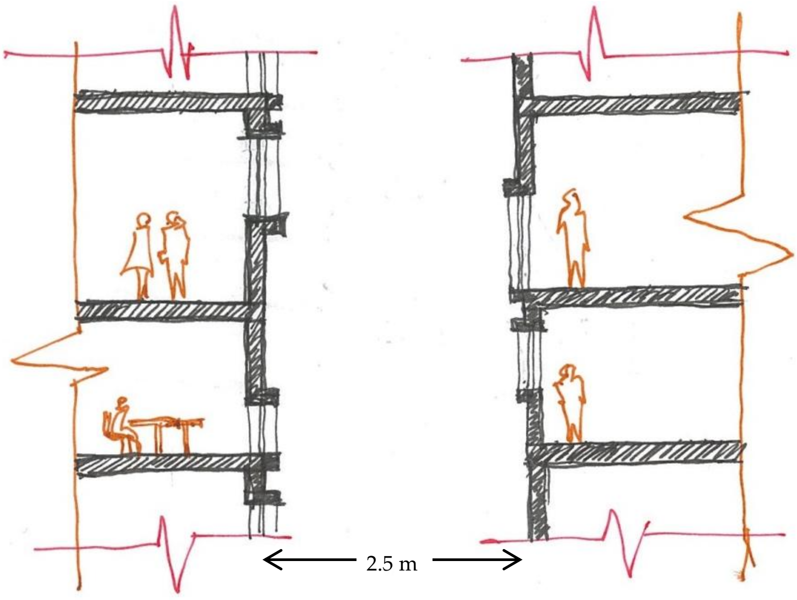


Figure 8-9: Conceptual section showing the sill and lintel height of the windows of the two buildings to be different from each other to increase visual privacy

<u>Objective 6: To ensure design features for the elderly and disabled</u>

Strategy 1: The building and the apartments should have the necessary design features such as ramps with the required slope according to the standards specified in the BNBC, handrails in toilets and bathrooms for the elderly and disabled.

Strategy 2: Elevators should be capable of fitting a stretcher.

Objective 7: To ensure affordability

Strategy 1: Apartments should be designed with variation in sizes.

Objective 8: To ensure that the neighbourhood has the facilities and amenities that occupants prioritize according to their needs in order to achieve an improved living environment

Strategy 1: Supermarket, pharmacy/medicine store, grocery shops, rickshaw/auto-rickshaw stand, mosque/worship place, playground, doctor's chamber, waste transfer station, technician services, park and laundry all need to be present in the neighbourhoods of high-rise residential buildings.

Strategy 2: Some of the facilities mentioned in Strategy 1 (supermarket, pharmacy/medicine store, grocery shops, mosque/worship place, doctor's chamber and laundry) could be accommodated on the lower levels of the buildings.

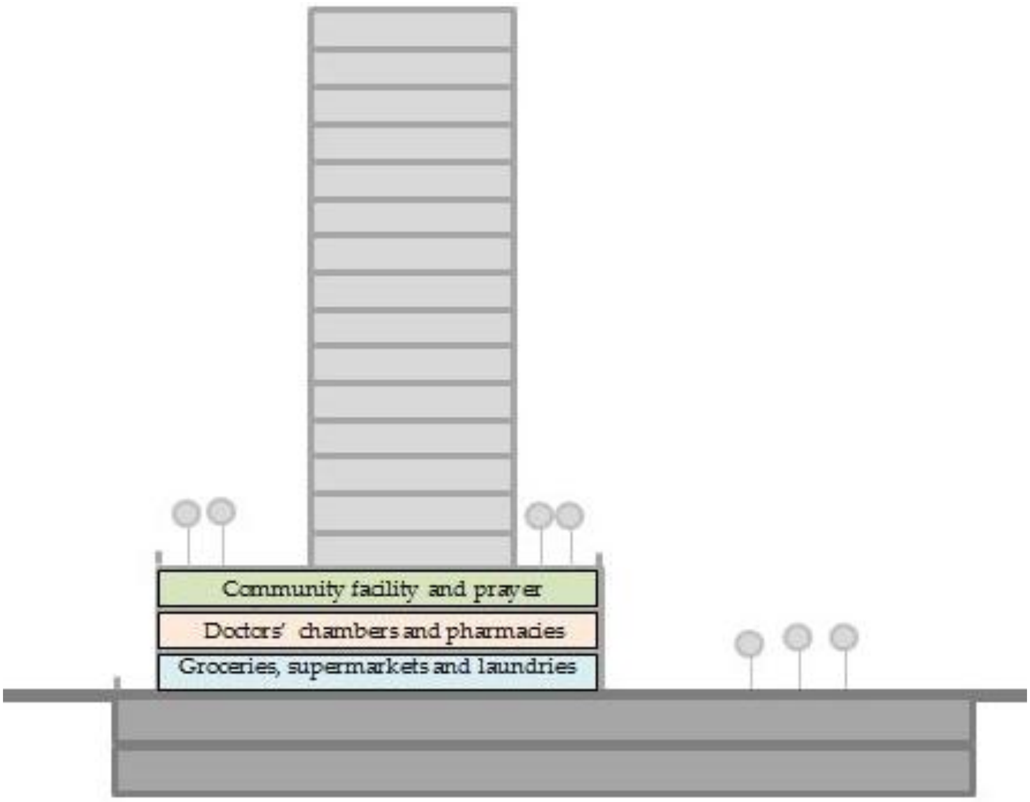


Figure 8-10: Conceptual section showing the neighbourhood facilities on the lower floors of the building

Objective 9: To ensure safety and security in private and public spaces within the building

Strategy 1: Effective community safety and security measures such as security guards in the building entrance to control unauthorised entry and close circuit cameras in the common spaces (corridors, staircases and lift lobby) must be employed and maintained to make the occupants feel safer.

Strategy 2: Burglar alarms should be deployed in all apartments of the buildings.

Objective 10: To ensure safety of children

Strategy 1: Particular attention should be given to safety for children on balconies and roofs.

8.4.3.2.4 Built environment

Table 8-9: Strategies on "Built environment"

Issue: Built environment	Study	Chapter	Section
Objective 1			
Strategy 1	Household questionnaire survey	Chapter 6	6.3.5.3.1
Strategy 2	Household questionnaire survey	Chapter 6	6.3.5.3.1
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.6
Objective 2			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.6
	Household questionnaire survey	Chapter 6	6.3.5.3.3
Strategy 2	Household questionnaire survey	Chapter 6	6.3.5.3.3

Objective 1: To ensure that a good standard of day-lighting and natural ventilation is provided

Strategy 1: The daylight factor must be at least 2.3% in bedrooms, at least 1.5% in living rooms, at least 2% in dining rooms and at least 2.2% in kitchens.

Strategy 2: The lower floors of the buildings (where occupants' perceived satisfaction of natural ventilation is not as good as the upper floors) could be designed for mixed-use purposes which are not entirely dependent on natural ventilation.

Strategy 3: The location of openings should promote both natural and cross ventilation.

<u>Objective 2: To maximise acoustic privacy for all occupants and prevent disturbances from external noise sources on lower floors</u>

Strategy 1: The walls of the apartments should be able to reduce external noise so that the internal noise level does not exceed 31 dBA.

Strategy 2: The floors on levels 1-10 should use appropriate noise attenuation treatments incorporated within the structure.

8.4.3.3 Construction stage

8.4.3.3.1 Construction practice

Table 8-10: Strategies on "Construction practice"

Issue: Construction practice	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
	Objective 2		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.6 & 5.3.4.2.7
	Objective 3		
Strategy 1	Household questionnaire survey	Chapter 6	6.3.5.3.2 & 6.3.6
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 4	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
	Objective 4		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
	Objective 5		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
Strategy 4	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7
	Household questionnaire survey	Chapter 6	6.3.7
Strategy 5	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.2.2
Strategy 6	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.2.2
Strategy 7	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.2.2
Strategy 8	Household questionnaire survey	Chapter 6	6.3.5.1

Issue: Construction practice	Study	Chapter	Section
Strategy 9	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.2.2
	Objective 6		
Strategy 1	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.2.2
	Objective 7		
Strategy 1	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.2.2
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.7

Objective 1: To ensure efficiency in overarching construction management

Strategy 1: The buildings should comply with national construction standards and building regulations.

Strategy 2: The environmental impact of constructing buildings should be considered.

Objective 2: To ensure safety for workers and pedestrians during building construction

Strategy 1: Practices that avoid building materials falling off during construction should be adopted.

Strategy 2: Practices that avoid construction accidents should be adapted.

Strategy 3: Construction workers should be educated on the importance of safety in building construction and be provided with the appropriate safety equipment.

Objective 3: To ensure safety of the occupants

Strategy 1: Construction quality and structural safety should not be compromised under any circumstances.

Strategy 2: Adequate structural strength should be ensured.

Strategy 3: A monitoring unit to ensure safe building construction should be deployed.

Strategy 4: Building construction rules and regulations should be updated.

Objective 4: To ensure construction practice that facilitates ease of construction and minimal material wastage

Strategy 1: Coordination about the size/amount of building materials with building design should be adopted to minimise waste.

Objective 5: To ensure safety of occupants under fire conditions

Strategy 1: The design of buildings and services should meet the fire safety standards in the BNBC (Bangladesh National Building Code).

Strategy 2: Easy accessibility of fire fighting vehicles to the building premises must be provided.

Strategy 3: Fire drills must be conducted by responsible fire wardens and management staff at regular intervals.

Strategy 4: Mandatory fire-fighting training for the staff and occupants of high-rise residential buildings must be provided.

Strategy 5: A monitoring unit needs to be set up by the relevant governing authorities to oversee efficient management of fire safety in the buildings

Strategy 6: The building services should have an emergency response team managed by responsible fire wardens, security staff and management staff.

Strategy 7: Fire protection measures need to incorporate an integrated fire safety system and an emergency management plan.

Strategy 8: Regular inspections of fire-fighting facilities should be made mandatory.

Strategy 9: High-rise residential buildings above 14 floors need to have the provisions of a helipad for evacuation in case of a major fire outbreak.

Objective 6: To ensure the building does not collapse during its design lifetime

Strategy 1: The building construction process should include the following:

- Vigilant monitoring and supervision by employing qualified and trained engineers;
- Provisions of safety inspections of key structural elements by qualified person after completion;
- An active monitoring unit set up by the relevant governing authorities to ensure that all standards are met;
- Quality approach in structural design, details and specifications; and

- Commitment to high standards of construction management and building safety beyond statutory duties.

Objective 7: To ensure the building does not collapse during natural disasters

Strategy 1: The design of buildings should include a multi-hazard approach that accounts for potential impacts of seismic forces as well as all major hazards.

Strategy 2: The structure of the building needs to be designed for maximum flexibility.

8.4.3.3.2 Building materials

Table 8-11: Strategies on "Building materials"

Issue: Building materials	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.8
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.8
Strategy 3	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.8
Strategy 4	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.8
Strategy 5	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.8

Objective 1: To ensure proper selection of building materials

Strategy 1: Durable building materials should be used.

Strategy 2: Building materials that are suitable for the site's climate should be used.

Strategy 3: Local building materials should be used.

Strategy 4: Non-hazardous building materials should be used.

Strategy 5: Materials that require minimum cleaning and maintenance should be used.

8.4.3.4 Building operation stage

8.4.3.4.1 Maintenance

Table 8-12: Strategies on "Maintenance"

Issue: Maintenance	Study	Chapter	Section
	Objective 1		
Strategy 1	Household questionnaire survey	Chapter 6	6.3.7
Strategy 2	Household questionnaire survey	Chapter 6	6.3.5.1

Strategy 3	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.4
Strategy 4	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.4
Strategy 5	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.4
Strategy 6	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.4
	Objective 2		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.4
	Objective 3		
Strategy 1	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.4

<u>Objective 1: To ensure regular maintenance of all building services, features and measures</u>

Strategy 1: The building authority should include a maintenance program with regular periodic inspections of building services.

Strategy 2: All building services, particularly fire-fighting facilities and elevators needs regular maintenance.

Strategy 3: A monitoring unit needs to be set up that would conduct post occupancy evaluation of all the building services and user satisfaction.

Strategy 4: Utility service charge should be made transparent.

Strategy 5: All the buildings should have a long-term maintenance plan.

Strategy 6: Training of building operations staff should be made mandatory.

<u>Objective 2: To ensure emergency preparedness planning</u>

Strategy 1: Emergency planning procedures should be part of the maintenance program.

<u>Objective 3: To ensure smooth flow of traffic in and out of the high-rises</u>

Strategy 1: The management staff in the buildings should be responsible for controlling traffic in and out of the buildings.

8.4.3.4.2 Resource management

Table 8-13: Strategies on "Resource management"

Issue: Resource management	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.9 &

			5.3.4.2.11
	Household questionnaire survey	Chapter 6	6.3.4.5
Objective 2			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.9
	Household questionnaire survey	Chapter 6	6.3.7
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.9
	Household questionnaire survey	Chapter 6	6.3.7
Strategy 3	Household questionnaire survey	Chapter 6	6.3.7
Strategy 4	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.9
Strategy 5	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.9
Objective 3			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.11
Objective 4			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.11
	Household questionnaire survey	Chapter 6	6.3.7
Objective 5			
Strategy 1	Household questionnaire survey	Chapter 6	6.3.6
Objective 6			
Strategy 1	Electricity use analysis	Chapter 7	7.3.4.2.2
Strategy 2	Electricity use analysis	Chapter 7	7.3.4.2.3

Objective 1: To ensure operational efficiency of all resources (water, gas and electricity) services

Strategy 1: Electricity, gas and water usage in the building need to be digitally metered.

Objective 2: To ensure conservation of water use

Strategy 1: The apartments should have water efficient plumbing fixtures, fittings and appliances.

Strategy 2: The buildings should harvest rainwater for purposes such as flushing toilets, washing cars and gardening.

Strategy 3: The buildings should use grey water for purposes such as flushing toilets, washing cars and gardening.

Strategy 4: The buildings should use and manage storm-water for landscaping.

Strategy 5: Water use during construction must be minimised.

Objective 3: To ensure efficient energy management during the construction stage of buildings

Strategy 1: Energy use during building construction stage must be minimised.

Objective 4: To ensure efficient energy management during the operational stage of buildings

Strategy 1: The apartments must have energy efficient lighting systems.

Objective 5: To ensure power smooth operation of elevators during power failure

Strategy 1: Standby power generators should be provided to support elevator use during power failures.

Objective 6: To reduce the total annual cooling electricity use

Strategy 1: Larger size apartments need to be on higher levels of the buildings.

Strategy 2: If air-conditioning is needed at all, high set-point temperature ranges should be used.

8.4.3.4.3 Waste management

Table 8-14: Strategies on "Waste management"

Issue: Waste management	Study	Chapter	Section
Objective 1			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.10
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.10
Objective 2			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.10
Objective 3			
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.10
Strategy 2	Stakeholder questionnaire survey	Chapter 5	5.3.4.2.10

Objective 1: To ensure efficient household waste management during the operational stage of building

Strategy 1: The building premise should have designated space with three bins for proper collection of waste in the building in cases where there is no door-to-door collection.

Strategy 2: The building should have garbage chutes for collecting organic household waste.

Objective 2: To ensure efficient management of construction waste on site

Strategy 1: Recyclable and recovered resources should be redirected to appropriate sites.

Objective 3: To ensure safety from hazardous waste on site

Strategy 1: Hazardous waste on site should be handled safely and stored separately.

Strategy 2: Use of hazardous materials like volatile organic compounds, timber preservatives, PVC, etc. should be avoided.

8.4.3.4.4 Awareness and education

Table 8-15: Strategies on "Awareness and education

Issue: Awareness and education	Study	Chapter	Section
	Objective 1		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.6
	Electricity use analysis	Chapter 7	7.3.4.2.3
Strategy 2	Household questionnaire survey	Chapter 6	6.3.7
Strategy 3	Critical review process: Presentation of draft strategies to stakeholders	Chapter 8	8.3.1.5
Strategy 4	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.6
	Objective 2		
Strategy 1	Household questionnaire survey	Chapter 6	6.3.7
	Objective 3		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.6
	Household questionnaire survey	Chapter 6	6.3.7
	Objective 4		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.6
	Household questionnaire survey	Chapter 6	6.3.7
	Objective 5		
Strategy 1	Stakeholder questionnaire survey	Chapter 5	5.3.4.1.6

Objective 1: To promote resource efficiency in buildings

Strategy 1: Effective public awareness programs on resource efficiency should be provided by the government on a macro scale and by the building management on a micro scale to increase the occupants ' awareness of electricity, water and gas usage. The occupants should be made aware that air conditioners, their usage time and set-point temperature ranges (low) are largely responsible for a higher consumption of cooling electricity use.

Strategy 2: The occupants should be encouraged by the government and the building management to participate in education and training programs on using resources efficiently.

Strategy 3: When apartment owners sign the document of flat ownership they should be informed/educated about water efficient fixtures and energy efficient lamps.

Strategy 4: The government should facilitate the development of curriculums for schools about resource efficiency.

Objective 2: To promote awareness on fire safety amongst the building occupants

Strategy 1: The occupants should be encouraged by the government and the building management to participate in education and training programs on fire safety.

Objective 3: To promote awareness on the effect of hazards such as natural disasters amongst the building occupants

Strategy 1: The occupants should be encouraged by the government and the building management to participate in education and training programs on emergency preparedness planning for natural disasters.

Objective 4: To ensure awareness of the occupants on waste disposal and recycling

Strategy 1: The occupants should be encouraged by the government and the building management to participate in education and training programs in efficient household management (three bins).

Objective 5: To ensure that the concerned stakeholders of the building construction industry are aware of sustainable building principles.

Strategy 1: Sustainable building principles should be made part of the training courses and accreditation for architects, planners, construction engineers and real estate developers.

8.5 Conclusion

This chapter addresses the research question of what should be the strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka. The study used an evidence-based approach, including a comprehensive literature review, field studies, stakeholder questionnaire survey, household questionnaire survey and electricity use data of the apartments in high-rise residential buildings in identifying the key elements for these strategies. The findings, based on this approach were used to develop a draft strategy which was validated by the stakeholders through a one-on-one discussion.

The study identified a total of five social issues and nine environmental issues in developing the strategies for high-rise residential buildings in Dhaka. The social component consisted of 22 objectives and 49 strategies, while, the environmental component consisted of 23 objectives and 55 strategies to achieve those objectives. A successful application of these strategies is very important in order to achieve the overall socially and environmentally sustainable practices for the high-rise residential building development in Dhaka. The application process would involve various actors, including architects, planners, engineers, developers, policy makers and building occupants at various stages of design, planning, building construction, building material production, operation and demolition of the buildings. In addition to the various stages at which the practices of high-rise residential buildings can be made socially and environmentally sustainable, the application process would also require the integration of these proposed strategies at the national and local planning level, with both short term and long-term implementation policies.

9 Conclusion

9.1 Introduction

This chapter presents the key findings and limitations of this research together with the recommendations for the strategies for socially and environmentally sustainable practice and the recommendations for further research.

9.2 Research questions answered and research objectives achieved

The overarching research question of this thesis "What are the strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka" was achieved by addressing four research questions and ten research objectives (Section 1.4). A summary of the objectives and the four research questions in conjunction with the findings are outlined as follows:

> *Research question 1: What are the socially and environmentally sustainable parameters for high-rise residential buildings that exist globally and what are the present initiatives and efforts for achieving sustainable high-rise residential buildings in Dhaka?*

In order to investigate the socially and environmentally sustainable parameters for high-rise residential buildings that exist globally an extensive literature review was conducted to understand the concepts of sustainable construction, sustainable building, sustainable high-rises and finally sustainable high-rise residential buildings. The socially sustainable parameters for high-rise residential buildings that exist globally were identified as: social interaction, planning and design issues such as open space, visual privacy, distance between buildings and flexibility in internal arrangement, education and awareness, safety and security and employment of local people. Similarly, the environmentally sustainable parameters for high-rise residential buildings that exist globally were identified as: ecological balance/impact, impacts on air, land and water, day-lighting, natural ventilation, construction practice, building materials, resource management (energy & water), waste management, site selection and site development and construction practice.

Another literature review was conducted to investigate the current efforts for achieving sustainable high-rise residential building residential buildings in Dhaka. This review found that no efforts have been made so far to develop sustainable high-rise residential buildings in Dhaka.

> *Research question 2: What, according to the stakeholders, are the criteria for achieving socially and environmentally sustainable practices for high-rise residential buildings?*

The research question of the stakeholders' criteria for achieving socially and environmentally sustainable practices for high-rise residential buildings was addressed through a stakeholder questionnaire survey in which 128 criteria on social and environmental issues were presented. The stakeholders were requested to rate each criterion based on a five point Likert scale, where "1" indicated "least important", "2" indicated "slightly important", "3" indicated "moderately important", "4" indicated "very important" and "5" indicated "extremely important". Out of the 37 criteria on social issues, 32 criteria received "high importance" based on the RII (Relative Important Index), whereas 46 out of the 91 criteria on environmental issues received "high importance".

> *Research question 3: What are the current conditions, problems, constraints and achievements of the high-rise residential buildings in Dhaka, Bangladesh?*

The research question of identifying the current conditions, problems, constraints and achievements of the high-rise residential buildings in Dhaka, was addressed through two household questionnaire surveys.

Objective 1: To investigate the perceptions of the respondents regarding height of high-rise residential buildings

In order to investigate the perceptions of the respondents regarding building height of high-rise residential buildings the respondents were asked about the following in the first questionnaire survey:

- The respondents' perceptions of advantages and disadvantages of living in high-rise residential buildings
- The respondents' perceptions of present floor level and building height
- The respondents' preferred floor level

The findings indicate that better natural ventilation, ample day-lighting, better security and less noise were among the most frequently cited advantages, whereas, lack of safety during fire, fear of structural safety and difficulty in using the stairs when the elevators were not working and when there was no electricity were among the most frequently cited disadvantages of living in high-rise residential buildings. The majority of the respondents on floors 6-15 said that where they live was just right, whereas quite a number of respondents on floors 16-20 thought that their present floor level was too high. About 96% of the respondents defined buildings that had 11-15 storeys as tall buildings and about 64% of the respondents considered buildings between 16-20 storeys as very tall buildings. The majority of the respondents preferred to live on floors between 11 and 15.

Objective 2: To examine the social and environmental conditions in the high-rise residential buildings

In order to examine the social and environmental conditions in the high-rise residential buildings, the first household questionnaire survey was able to identify the following:

- Socio-economic conditions of the respondents
- Safety and security in the buildings
- Maintenance issues in the buildings
- The respondents' awareness of energy, water and gas conservation and household waste management
- Interaction with architect and developer during the design and construction phase
- Spatial design issues consisting of
    - Physical characteristics of the buildings
    - Design characteristics of the buildings
    - Interaction with neighbours
    - Playing space for children
    - Open space
    - Visual privacy
    - Inclusiveness of opportunity
- Environmental issues consisting of
    - Day-lighting and natural ventilation
    - Fire safety
    - Pollution
    - Household waste management
    - Resource management

Objective 3: To identify the importance of the recommended neighbourhood facilities

In order to identify the importance of the 30 neighbourhood facilities recommended by DAP (Detailed Area Plan) for a neighbourhood, the respondents were asked to rank their importance. Out of the 30 neighbourhood facilities, supermarket, pharmacy/medicine store, grocery shops, rickshaw/ auto-rickshaw stand, mosque/worship place, playground, doctor's chamber, municipal waste collection point, technician services (electrical, plumber, air conditioner, freezer),park and laundry shop were ranked with "high" importance. In addition, the neighbourhoods around five case study buildings were surveyed to study the 30 neighbourhood facilities recommended by DAP for Dhaka.

Objective 4: To identify the factors that need improvement for increasing satisfaction in high-rise living

In order to identify the factors that need improvement for increasing satisfaction in high-rise living, the building attributes identified from the literature review, were asked to be ranked by respondents in the second household questionnaire survey. Out of the attributes on social satisfaction, the availability of neighbourhood facilities and regular inspections as part of the maintenance issues have been identified as areas where attention is needed in order to improve respondents' satisfaction. Similarly, out of the attributes on spatial design issues, size of secondary bedrooms, size of dining room and living room, efficiency of community space, visual privacy, open space around the building, setback distance, storage facilities, space for interaction with neighbours, playing space for children and design features for the elderly and disabled all need improvement for increasing respondents' satisfaction of high-rise living. None of the attributes on environmental satisfaction (day-lighting, natural ventilation, building construction, household waste management, noise level and resource management) received "high" levels of satisfaction and thus need improvements.

Objective 5: To identify the concerns regarding high-rise living

In order to identify the concerns regarding high-rise living, general concerns of high-rise living, identified from literature review, were asked to be ranked by the respondents in the second household questionnaire survey. The findings show that fire risk, structural safety, lack of playing space for children, elevator breakdown, power failure, lack of social interaction, lack of visual privacy and water crisis were identified as concerns of "high" level.

Objective 6: To explore the behavioral responses of the respondents of high-rise residential buildings in regards to social and environmental issues of living in high-rise residential buildings

In order to explore the behavioural responses of the respondents of high-rise residential buildings in regards to social and environmental issues of living in high-rise residential buildings, the first household questionnaire survey consisted of questions that were designed to examine the willingness and affordability of the respondents to have/use certain design features and facilities. In addition, the willingness of the respondents to undertake educational and training programs on fire safety, emergency preparedness during natural disasters such as earthquake, efficient electricity and water use and efficient household waste management were also investigated in the first household questionnaire survey. The findings show that the respondents expressed a "high level of willingness" to have (pay) for the following provisions: more fire security measures, more security measures at the building entrance, apartment and common spaces, energy efficient lighting system, water efficient fixtures and fittings, design consideration for the disabled and elderly people, elevators, large enough to fit a wheelchair and stretcher, playing space for children, well-designed interactive community spaces, inspections for maintenance purposes, gym and game facilities, rainwater and grey water, more open space and roof gardens. In addition, the respondents expressed "high level of willingness" to all six educational and training programs on fire safety, emergency preparedness during natural disasters such as earthquake, efficient electricity, water and gas management and efficient household waste management.

Research question 4: What are the factors that affect electricity use in high-rise apartments?

Objective 7: To determine the electricity use of the apartments in the high-rise residential buildings

In order to define the electricity use of the apartments in the high-rise residential buildings, the monthly electricity use data for one year were collected from 342 apartments. Based on the monthly electricity use data, the annual cooling electricity use was calculated.

Objective 8: To explore the influence of temperature, relative humidity and wind speed on electricity use.

Correlation was used to analyse the influence of apparent temperature on the average monthly electricity use of the 342 apartments. Both mean monthly electricity use and mean monthly cooling electricity use was found to be strongly related to the apparent temperature.

Objective 9: To identify the design and household characteristics that influence electricity use

In order to identify the design characteristics that influence electricity use, six design characteristics were identified from the literature review in Chapter 3 as key features that can play a role in influencing electricity use in high-rise apartments. These six design characteristics were studied while the electricity use records were collected from the 342 apartments in eight case study buildings. Linear backward regression analysis was used to analyse the influence of design and household characteristics on total annual electricity use and total annual cooling electricity use/total annual air-conditioning electricity use.

Apartment size and total window area were the statistically significant predictors that influenced total annual electricity use when the effects of household characteristics (household size and number of air conditioners) were not considered. However, when the effect of both design and household characteristics were taken into consideration, apartment size, effective canyon ratio and number of air conditioners were the statistically significant predictors of total annual electricity use.

Floor level and apartment size were the statistically significant predictors that influenced total annual cooling electricity use, when the effects of household characteristics were not considered. Apartment size and number of air conditioners were the statistically significant predictors that influenced total annual air-conditioning electricity use, when the effect of both design and household characteristics were taken into consideration.

Objective 10: To explore the household practices that influence electricity use

In order to explore the household practices that influence electricity use, the household practices such as air conditioning usage time and preferred set-point temperature ranges of air conditioners were also investigated during a detailed household survey. Linear backward regression analysis was used to analyse the influence of household practices on total annual air-conditioning electricity use. The findings showed that total annual air-conditioning electricity use increased with lower set-point temperature ranges of air conditioners, and that it increased with the increase in usage time of air conditioners.

9.3 Contributions of this research

This research has used an evidence-based research paradigm based on: (1) a comprehensive literature review, (2) household questionnaire survey, stakeholder questionnaire survey, (3) field studies (physical survey of high-rise residential buildings and their neighbourhoods) and (4) electricity use records of the apartments in order to develop the strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka (Chapter 8). As shown in Figure 9-1, this research has identified a total of five social issues and nine environmental issues in developing the strategies for socially and environmentally sustainable practices for high-rise residential buildings in Dhaka. The social component consisted of 22 objectives and 49 strategies, while, the environmental component consisted of 23 objectives and 55 strategies to achieve those objectives Figure 9-1).

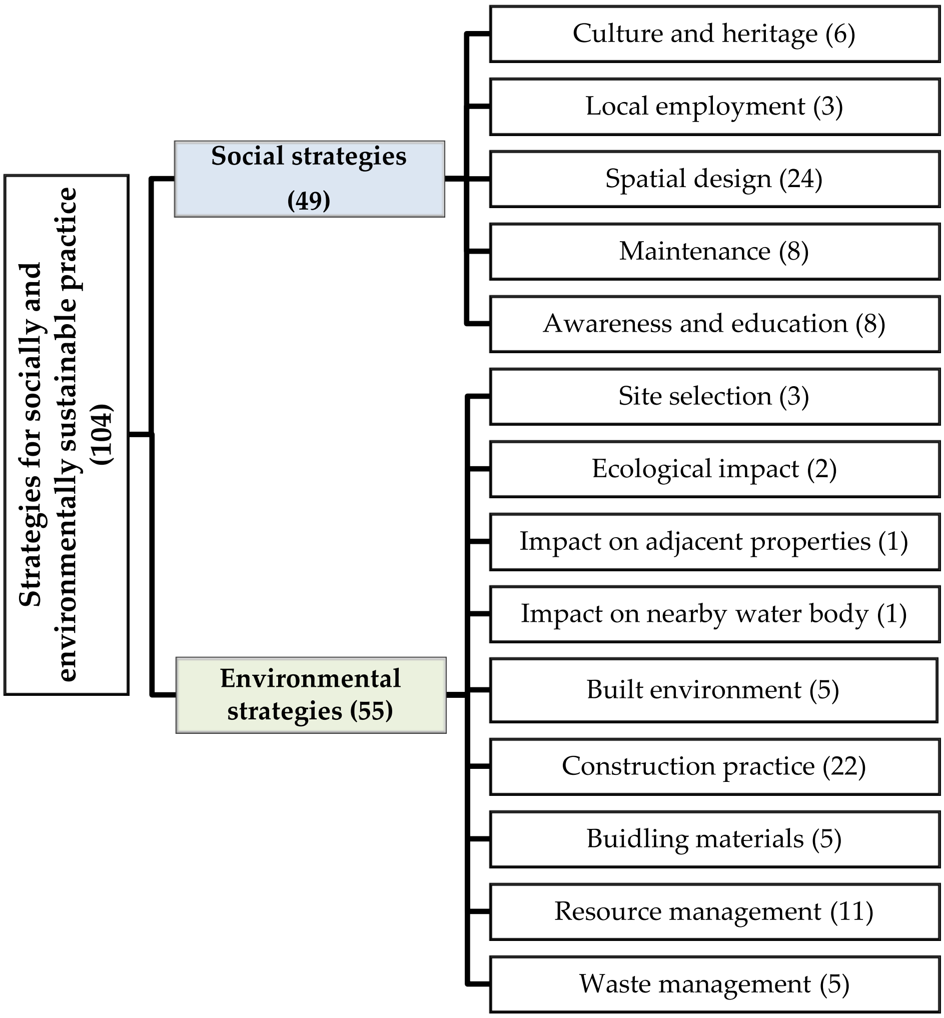


Figure 9-1: Strategies for socially and environmentally sustainable practices for high-rise residential buildings

It is anticipated that the implementation of these strategies on a national level by the BNBC (Bangladesh National Building Code), IAB (Institute of Architects), BIP (Bangladesh Institute of Planners), IEB (Institution of Engineers, Bangladesh) and REHAB (Real Estate & Housing Association of Bangladesh), would contribute to improving, if not totally eradicating the five negative environmental consequences and four inappropriate development practices in Dhaka (Section 1.2.1).

The implementation of these strategies is expected to improve all the key identified social and environmental problems (Table 1-1) of high-rise residential buildings in Dhaka. In addition, the thesis itself could become a useful reference document for subsequent studies in other cities around the world grappling with similar challenges. The research has revealed interesting and valuable findings related to high-rise living in Dhaka, beneficial for planning purposes, as well as in the design and layout of new apartments and in the electricity consumption of the apartments. The equations used to quantify energy use can be used by various stakeholders and building occupants to evaluate their decisions in relation to electricity consumption.

The strategies for socially sustainable practices developed in this research emphasise adding value to the quality of life by focusing on maintaining culture and heritage, local employment, spatial design, maintenance and awareness and education , whereas, the strategies for environmental practices focus on proper site selection, reducing the impact on ecology, adjacent property and nearby water body together with improving the built environment, construction methods, building materials, resource efficiency with emphasis on occupant behaviour and household practices and waste management.

It can also be added that even though the strategies developed in this research are dispersed widely among a broad category of issues, the main emphasis has been on issues regarding spatial design, construction practice, resource management, maintenance and awareness and education. This research also stresses the importance of household practices as it has demonstrated that household practices have greater influence on electricity use, compared to design characteristics. Thus, this research highlights the importance of awareness and education of the respondents on resource efficiency because any changes on design characteristics of the buildings may not have much impact on the electricity use of the buildings without the respondents operating their dwellings in a way that will help minimise electricity use. The success of these strategies to achieve sustainable high-rise residential buildings therefore lies in practices that address both social and environmental issues.

9.4 Limitations of this research

The research has achieved the overall aim of formulating strategies for socially and environmentally sustainable practice in high-rise residential buildings of Dhaka. However, due to the limited time frame and funding of this research, the strategies developed could not be implemented in a real project. A review process was undertaken, in which the draft strategies were presented to the stakeholders for their feedback, and the final strategies were formulated based on their feedback.

Another limitation of this research was that internal monitoring of indoor temperature, humidity and wind speed was not taken due to constraints in the availability of measuring devices.

9.5 Recommendations for the strategies

It should be noted that while this research is the first step towards achieving socially and environmentally sustainable high-rise residential buildings in Dhaka, more innovative strategies could be explored. However, the lessons learnt from this research indicate that any new suggestion must be evidence-based.

It is anticipated that in the future, the proposed strategies would need to be updated and modified based on the new requirements of occupants when the baseline for socially and environmentally sustainable practice for high-rise residential buildings has improved. If the strategies outlined in this research are to be implemented, it is recommended that they be adjusted over time.

9.6 Recommendations for further research

The following areas are recommended for further study of high-rise residential buildings in Dhaka:

- Focus group discussions in the beginning of this research could have confirmed and refined the questions asked in the survey. This could not be done in this research due to time constraints and location of the research. However, in this research, a pilot study was conducted to test the survey questions. Further studies on such research may benefit from using a research design that considers input from focus groups at the early stages of the research.
- In order to engender stronger social and environmental sustainable outcomes in high-rise residential buildings, new and alternate ways of living, or alternate construction practices could be a possible realm of further investigation.
- An investigation of the influence of wind speed at different floor levels on the cooling electricity use and the impact of inlet and outlet design of windows on the natural ventilation in the apartments could be further investigated.
- A close monitoring of the usage of all the household appliances for a period of time to study the combined influence of design characteristics, household characteristics (with socio-economic parameters), household behaviour and household appliances on electricity use could be further investigated.

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Appendices

Appendix A: Stakeholder Questionnaire Survey Documents

A-1 Participant Information Sheet

THE UNIVERSITY OF ADELAIDE AUSTRALIA

PARTICIPANT INFORMATION SHEET

STAKEHOLDER QUESTIONAIRRE SURVEY

Data Collection: Sustainable High-rise Housing: the Context of Dhaka, Bangladesh

I am a Bangladeshi PhD student at the School of Architecture, Landscape Architecture & Urban Design, University of Adelaide, Australia. My research topic is "Sustainable High-rise Housing: the Context of Dhaka, Bangladesh”. This study aims to develop a framework for sustainability in high-rise housing in Dhaka. The framework proposed in this study could be used to set the criteria for sustainability in high-rise housing in Dhaka. In order to create a suitable assessment framework for Dhaka, it is essential to understand the most important concerns of building stakeholders in pursuing sustainable building development in Dhaka.

Therefore, I would like to invite you to participate in a questionnaire survey that consists of issues that may be important in developing sustainable high-rise buildings in Dhaka. The survey should take about 15-20 minutes to complete. The findings from the survey will be an integral part of the research, leading to the thesis that will be submitted for the degree of Doctor of Philosophy.

Your participation in this interview survey is completely voluntary. You may withdraw from it whenever you desire by simply advising the researcher of your intention to do so. After the questionnaire is collected, the data obtained will be anonymously code-recorded by the researcher. You will not be identifiable in any way by the collected data as well as in the published results.

The results will be confidential and will only be seen by the researcher. You do not need to give your name when completing the survey. The information obtained from the survey will be discussed with the researcher’s supervisors, and/or other post-graduate students in the School of Architecture, Landscape Architecture and Urban Design at The University of Adelaide. If you wish, a summary of the interview and questionnaire will be forwarded to you for confirmation of accuracy.

This project has received Ethics Approval from the University's Human Research Ethics Committee. Information about the Independent Complaint Procedure and the role of the Human Ethics committee is provided on a separate sheet.

For any further information, please do not hesitate to contact us:

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Dhaka-1207,Bangladesh
Ph. +61431866320 (Australia), 01767695977 (Bangladesh)
Email: tahmina.ahsan@adelaide.edu.au

I am looking forward to receiving your positive reply and I do appreciate your participation in this research project.
Yours Sincerely,
Tahmina Ahsan

A-2 Consent Form

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

STANDARD CONSENT FORM
FOR PARTICIPANTS (STAKEHOLDERS) IN THE RESEARCH PROJECT

Participant to complete:

1. I ....(please print name) have read the attached Information Sheet and agree to take part in the research project titled : **Sustainable High-rise Housing: the Context of Dhaka, Bangladesh**

2. I acknowledge that I have read the attached '**Participant Information Sheet'**

3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

4. Although I understand the purpose of the research project it has also been explained that involvement may not be of any benefit to me.

5. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

6. I understand that I am free to withdraw from the project at any time and I realize that this project will not affect me now and in the future.

7. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

Signature: .... Date: ....

Witness to complete:

I have described to.. (name of subject) the nature of the research to be carried out and in my opinion she/he understood the explanation.

Status in Project: **Researcher-PhD Candidate**

Name: **Tahmina Ahsan**

Signature: .... Date: ....

A-3 Stakeholder Questionnaire Survey

THE UNIVERSITY OF ADELAIDE AUSTRALIA

STAKEHOLDER QUESTIONNAIRE SURVEY

Part 1: Background information

1. Name (optional): [ ]

2. Contact number/email [ ]

3. Profession (please tick)

Architect		Planner	
Real Estate Developer		Engineer	
Policy Maker			

4. Years of Working Experience in your profession (please tick)

1-5 years		6-10 years	
11-15 years		16-20 years	
21-25 years		26-30 years	
More than 30 years			

Part 2: High-rise height and open space

5. Please suggest the building height of high-rise residential buildings.

[ ]

6. Please suggest the percentage of space that must be left open in a site.

[ ]

Part 3: Stages at which sustainable issues can be applied

7. Please indicate by placing a "tick" for each of the stages where you think sustainability issues can be incorporated.

	Least suitable	Slightly suitable	Moderately suitable	Very suitable	Extremely suitable
	1	2	3	4	5
Planning					
Design					
Building construction					
Building material production					

	Least suitable	Slightly suitable	Moderately suitable	Very suitable	Extremely suitable
	1	2	3	4	5
Building material production					
Operation					
Demolition					

Part 4: Preference of criteria for sustainable high-rise residential buildings

8. When planning, designing and building a new high-rise residential building, please place a "tick" in the appropriate box to show the priority of each criterion for the environmental issues below:

Environmental issues	Least important	Slightly important	Moderately important	Very important	Extremely important
	1	**2**	**3**	**4**	5
A Site selection					
Agricultural or ecological value of site should be conserved					
Redevelopment of existing site rather than working on a new site					
Flooding risk of the site should be assessed					
The seismic characteristic of the site should be considered					
Other...					
B Ecological impact					
Considerations of damage to existing soil, water bodies and flora and fauna of the site and adjacent land due to construction process					
Site that is ecologically sensitive should not be developed and any damage to ecology should be minimised					
Conservation of the site's biodiversity					
Other...					
C Impacts on adjacent properties					
Minimise obstruction of daylight to adjacent properties					
Minimise potential glare to adjacent properties					
Minimise noise pollution during the construction					
Minimise obstruction of wind to adjacent properties					
Minimise impacts on view					
Minimise water pollution during construction of the building					
Minimise impacts from site workers' accommodation					
Other...					
D Impacts on air					
Air pollution during construction					
Air pollution from all energy used for					

Environmental issues	Least important 1	Slightly important 2	Moderately important 3	Very important 4	Extremely important 5
building operation					
Other...					
E Impacts on nearby water body					
Restriction of water contamination in nearby water body during the building construction					
Restriction of water contamination in nearby water body during the building operation					
Other...					
F Water management					
Use of recycled water (grey water) for landscape					
Use of recycled water (grey water) for testing of fire-fighting system					
Use of recycled water (grey water) for cooling system					
Use of recycled water (grey water) for flushing in toilets					
Use of recycled water (grey water) for construction					
Use of water efficient plumbing fixtures, fittings and appliances					
Use of digital water meter in each apartment to monitor water use					
Use and management of storm-water for landscaping					
Use of runoff water from roof and rainwater harvesting					
Minimise water use during construction					
Other...					
G Waste management					
Designated space for proper collection of waste in the building					
Waste bins of appropriate size for organic waste					
Waste bins of appropriate size for recyclables					
Waste bins of appropriate size for non-recyclables					
Local composting facility in each building					
Collaboration with other building users so that waste can be treated 'regionally'					
On-site wastewater treatment systems for grey water and black water					
Construction and demolition waste management program with sorting, reuse and recycling measures					
Staff induction on waste management					
Procurement/purchasing policies that support waste avoidance					

Environmental issues	Least important 1	Slightly important 2	Moderately important 3	Very important 4	Extremely important 5
Construction waste minimization on site by making use of leftover materials and packaging materials					
Redirection of recyclable, recovered resources back to appropriate sites					
On-site sorting of construction waste for collection and recycling					
Avoiding the use of hazardous materials like volatile organic compounds, timber preservatives, PVC, etc.					
Garbage chutes in each building					
Safe handling and storage of hazardous waste on site					
Other...					
H Construction management					
Compliance to national construction standards and building regulations					
Updating of building construction rules and regulations					
Repeatability in design and use of standardised prefabricated building components					
Design for easy disassembly, reuse or recycling of components					
Reuse of suitable existing structure on the site as part of the new building					
Reduced use of virgin/new material					
Use of recycled building materials					
Reduced use of building materials and finishes from overseas					
Use of local building materials					
Use of salvaged, refurbished or used materials from off-site sources					
Products and materials with recycled content					
Use of durable materials					
Use of non-hazardous materials					
Building materials that are suitable for the site's climate					
Building materials with low-embodied energy					
Modular structure of the walls and glazing for ease of construction, minimal material wastage and to support future material reuse					
Co-ordination about material size with building design to minimise waste					
Use of certification systems for construction processes					
Data gathering processes for monitoring recovery, recycled and landfill materials					

Environmental issues	Least important 1	Slightly important 2	Moderately important 3	Very important 4	Extremely important 5
Building design that meets fire safety standards in the BNBC (Bangladesh National Building Code)					
Consideration of environmental impact of constructing buildings					
Provision of easy accessibility of fire fighting vehicles to the building premises					
Fire drills must be conducted by responsible fire wardens and management staff at regular intervals.					
Provision of mandatory fire-fighting training for the staff and occupants of high-rise residential buildings					
Ensure adequate structural strength					
A monitoring unit to ensure safe building construction					
Construction workers should be provided with the appropriate safety equipment.					
Other...					
I Indoor environmental quality					
Location of openings to promote natural and cross ventilation					
Adequate daylight in all spaces					
Glare control					
Reducing external and internal noise by using sound insulation materials					
Preventing ingress of external odour					
Other...					
J Energy management					
On-site secondary power generation systems, e.g. photovoltaic, etc.					
Use of wind turbine on roofs to generate electricity					
Use of digital electricity meters in each flat					
Use of electrical sub-meters in each flat for major consuming appliances to monitor energy usage					
Use of energy-star ratings for electrical appliances					
Use of digital gas meters in each apartment					
Minimise energy use during building construction stage					
Lighting fixture efficiency					
Dimmable and /or auto-censored lighting system					
Passive design features to reduce energy usage					
Air conditioning system efficiency					
Other...					

9. When planning, designing and building a new high-rise residential building, please place a "tick" in the appropriate box to show the priority of each criterion for the social issues below:

Social	Least important 1	Slightly important 2	Moderately important 3	Very important 4	Extremely important 5
K Safety and security					
Safety and security against theft by employing security measures at the building entrance, corridors, staircases, roof and common spaces					
Practices that avoid building materials falling off during construction should be adopted					
Practices that avoid construction accidents should be adapted					
Safety for children on balconies & roofs					
Other...					
L Inclusiveness of opportunities					
Ramps, handrails and other necessary design features for the elderly and people with disability					
Elevators capable of fitting a stretcher					
Other...					
M Human health and well-being					
Design considerations for people with acrophobia					
Adequate room size					
Proper size and day-lighting of circulation areas (lobby, hallways, stairs)					
Impacts on visual privacy from adjacent buildings need to be minimised					
Orientation of the building					
Visual access to exterior views					
Adequate open space must be provided					
Adequate storage space					
Other...					
N Education and awareness					
Sustainable building principles to be made part of the training courses and accreditation for architects, planners, construction engineers and developers					
Children at the primary level should be taught about resource efficiency					
Construction workers should be educated on the importance of safety in building construction.					
Occupants' awareness on electricity, water and gas usage should be increased through effective public awareness programs on resource efficiency					
Education and training of occupants on waste disposal and recycling issues					
Occupants' awareness on effects of natural					

Social	Least important 1	Slightly important 2	Moderately important 3	Very important 4	Extremely important 5
hazards should be increased through effective public awareness programs on emergency planning					
Other...					
O Social interaction					
Interaction of the users with the design team during the concept and design development phase to ensure that their needs are fulfilled					
Participation of the affected community in the development process to avoid conflict					
Interdisciplinary work among the involved groups from the beginning of the design process					
Spaces for social interaction and playing space for children, for e.g. community spaces, landscaped open space at the ground level, roof garden, etc.					
Recreational facilities like gym, sports facilities and game room					
Other...					
P Culture and heritage					
Considerations of local cultural values					
Relationship of design with existing streetscape					
Maintenance of heritage value at urban level					
Other...					
Q Local people and employment					
Use experienced and local design team					
Use experienced and local contractor					
Use experienced and local construction worker					
Other...					
R Flexibility and efficiency					
Variation in apartment size					
Open plan					
Maximise plot ratio					
Plan spaces for maximum flexibility					
Design structure for maximum flexibility					
Mixed-use can be incorporated in the design of high-rise residential buildings					
Other...					
S Building maintenance					
Materials that require minimum cleaning and maintenance					
Long term maintenance plan					
Emergency preparedness planning/ contingency planning procedures					
Training of building operations staff for building maintenance should be made					

Social	Least important **1**	Slightly important **2**	Moderately important **3**	Very important **4**	Extremely important **5**
mandatory.					
Other..					

Appendix B: Household Questionnaire Survey-1 Documents

B-1 Participant Information Sheet

THE UNIVERSITY OF ADELAIDE AUSTRALIA

PARTICIPANT INFORMATION SHEET

HOUSEHOLD QUESTIONNAIRE SURVEY

Data Collection: Sustainable High-rise Housing: the Context of Dhaka, Bangladesh

I am a Bangladeshi PhD student at the School of Architecture, Landscape Architecture & Urban Design, University of Adelaide, Australia. My research topic is "Sustainable High-rise Housing: the Context of Dhaka, Bangladesh”. This study aims to develop a framework for sustainability in high-rise housing in Dhaka. The framework proposed in this study could be used to set the criteria for sustainability in high-rise housing in Dhaka. In order to create a suitable assessment framework for Dhaka, it is essential to understand the present scenario of residential high-rise living in Dhaka.

Agency X (Real Estate Developer/ Architect/ High-rise Care-taker), alternatively Mr./Mrs.________________ has passed on this invitation and personally identifiable information has not been passed on to the researchers. The researcher will have an assistant with her while she visits the high-rise residential buildings.

Therefore, you are invited to participate in a questionnaire survey to understand the current conditions, problems, constraints of high-rise residential buildings. The survey should take about 15-20 minutes to complete. The findings from the survey will be an integral part of the research, leading to the thesis that will be submitted for the degree of Doctor of Philosophy.

Your participation in this interview survey is completely voluntary. You may withdraw from it whenever you desire by simply advising the researcher of your intention to do so. After the questionnaire is collected, the data obtained will be anonymously code-recorded by the researcher. You will not be identifiable in any way by the collected data as well as in the published results.

The results are confidential and will only be seen by the researcher. You do not need to give your name when completing the survey. The information obtained from the survey will be discussed with the researcher’s supervisors, and/or other post-graduate students in the School of Architecture, Landscape Architecture and Urban Design at The University of Adelaide. If you wish, a summary of the interview and questionnaire will be forwarded to you for confirmation of accuracy.

This project has received Ethics Approval from the University’s Human Research Ethics Committee. Information about the Independent Complaint Procedure and the role of the Human Ethics committee is provided on a separate sheet.

For any further information, please do not hesitate to contact us:

Assoc. Prof. Dr. Veronica Soebarto (Principal Supervisor)
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Dhaka-1207, Bangladesh
Ph. +61431866320 (Australia), 01767695977 (Bangladesh)
Email: tahmina.ahsan@adelaide.edu.au
I am looking forward to receiving your positive reply and I do appreciate your participation in this research project.

Yours Sincerely,
Tahmina Ahsan

B-2 Consent Form

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

STANDARD CONSENT FORM
FOR PARTICIPANTS (HOUSEHOLDS) IN THE RESEARCH PROJECT

Participant to complete:

1. I ....(please print name) have read the attached Information Sheet and agree to take part in the research project titled : **Sustainable High-rise Housing: the Context of Dhaka, Bangladesh**

2. I acknowledge that I have read the attached '**Participant Information Sheet**'

3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

4. Although I understand the purpose of the research project it has also been explained that involvement may not be of any benefit to me.

5. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

6. I understand that I am free to withdraw from the project at any time and I realize that this project will not affect me now and in the future.

7. I agree to the researcher taking photographs of the interiors and exteriors my house.
   Yes ☐ No ☐

8. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

Signature: .... Date: ....

Witness to complete:

I have described to.. (name of subject) the nature of the research to be carried out and in my opinion she/he understood the explanation.

Status in Project: **Researcher-PhD Candidate**

Name: **Tahmina Ahsan**

Signature: .... Date: ....

B-3 Household Questionnaire Survey-1

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Part 1: Personal characteristics of the respondents

1. Name (optional):
2. Address:
3. Contact number/ email (optional):
4. Age:
5. Gender:
6. Profession:

7. Please specify the number of members in your flat, according to the specified age group.

Age Group	Number of households	Age Group	Number of households
0-4		5-9	
10-14		15-24	
25-34		35-44	
45-59		60-69	
70-80		Above 80	

8. Please indicate the highest education level of the adult family members in your household including yourself.

Family members	Primary school	Secondary school	Higher secondary	University graduate	Postgraduate
Member 1	□	□	□	□	□
Member 2	□	□	□	□	□
Member 3	□	□	□	□	□
Member 4	□	□	□	□	□
Member 5	□	□	□	□	□
Member 6	□	□	□	□	□
Member 7	□	□	□	□	□
Member 8	□	□	□	□	□

Others: Specify____

9. What is the total monthly household income? (TK):

□	<25,000	□	50,001-80,000
□	25,000-50,000	□	80,001-100,000
□	>100,001	□	Other: Specify_____

10. What is the type of housing ownership?

□	Rent	□	Own, without debts

□	Own, but mortgaged (loan from bank)	□	Other: Specify_____

11. How long have you been living in this apartment?

□	< 1 year	□	6-10 years
□	1-5 years	□	11-15 years
□	> 15 years		

Part 2: Social issues

12. If you live on a higher floor, are there any disadvantages of living on a higher floor?
    □ No □ Yes □ Don't know

13. What are the advantages of living on higher floors?

14. What are disadvantages of living in high-rise residential buildings?

15. In terms of the floor you are living in, please indicate your perceived height of present floor level.

Floor level	Don't care	Too high	Not high enough	Too low	Just right
1st -5th floor	□	□	□	□	□
6th-10th floor	□	□	□	□	□
11th-15th floor	□	□	□	□	□
16th-20th floor	□	□	□	□	□
21st-25th floor	□	□	□	□	□

16. What is your perception of the height of a high-rise residential building?

□	1-5 storeys	□	16-20 storeys
□	6-10 storeys	□	21-25 storeys
□	11-15 storeys		

17. If you had the option of choosing your present floor level, which floor would have preferred to live in?

□	1-5 storeys	□	16-20 storeys
□	6-10 storeys	□	21-25 storeys
□	11-15 storeys		

18. If you live on a higher level of this building, are you or any member in your family afraid of heights?
    □ No □ Yes □ N/A
19. Is there any disabled/ handicapped person in your flat?

□ No □ Yes

20. What is the monthly expense (in TK) for various utility services?

Utility services	Montly expences (TK)
Electricity	
Gas	
Water	
Waste collection	
Service (elevator, generator, common lighting in stairs, guard, caretaker, gardener)	

21. Please indicate if the monthly expenses on utility services is:

□ Too low □ About right
□ Slightly low □ Very high
□ Extremely high □ N/A

22. Please indicate if the rent that you pay is:

□ Too low □ About right
□ Slightly low □ Very high
□ Extremely high □ N/A

23. If you own a vehicle is the parking facility sufficient?

□ No □ Yes □ Other

24. How would you rate the overall condition of the building?

Poor □ Very good
Somewhat good □ Excellent
Moderately good

25. Does this building have safety and security measures for users to access the building?

□ No □ Yes

26. How would you rate the security level of the building

□ Poor □ Very good
□ Somewhat good □ Excellent
□ Moderately good

27. Please assess the following infrastructure/services of your building

Infrastructure/services	Poor	Somewhat good	Moderately good	Very good	Excellent
Elevator	□	□	□	□	□

Staircase	□	□	□	□	□
Electrical services	□	□	□	□	□
Plumbing	□	□	□	□	□
Sewage	□	□	□	□	□
Water drainage	□	□	□	□	□
Fire-fighting facility	□	□	□	□	□
Cleanliness of common space (lobby, staircase, corridor)	□	□	□	□	□

28. Does the building carry out regular inspections

□ No □ Yes

29. How frequent are the regular inspections on the following services carried out in your building?

Services	Every three months	Every six months	Once a year	Never
Electrical installations	□	□	□	□
Water connection	□	□	□	□
Gas connection	□	□	□	□
Drainage systems	□	□	□	□
Fire services	□	□	□	□
Elevators	□	□	□	□

30. Have you ever noticed any public information program on the following?

Services	No	Yes
Electrical installations	□	□
Water connection	□	□
Gas connection	□	□
Household waste management	□	□

31. If you are the owner of this flat how would you rate your level of interaction with the architect, developer, etc.?

□	Poor	□	Very good
□	Somewhat good	□	Excellent
□	Moderately good	□	N/A

32. Please give information of the following physical characteristics of your building and apartment :

Total number of floors in the building	
Total number of apartments per floor	
Total number of elevators per floor	
Apartment size	
Number of bedrooms	

Number of living rooms	
Number of dining rooms	
Number of kitchens	
Number of bathrooms	
Number of servant's room	
Number of servant's toilets	
Number of storage rooms	

33. How important do you think it is to interact with your neighbours/ other people in the different apartments of the building?

- ☐ Not important
- ☐ Somewhat important
- ☐ Moderately important
- ☐ Very important
- ☐ Extremely important

34. Where do you interact with your neighbours?

35. Where do your children play?

36. Does your building occupy the whole land area?

☐ No ☐ Yes

37. Do you need more open/ green space?

☐ No ☐ Yes

38. Does the apartment include a garden/green space in any of the following spaces? Please tick as many as apply.

☐ Ground floor ☐ Roof ☐ Balcony ☐ None

39. How is the visual privacy from the exterior in principal areas of dwelling units?

- ☐ Not private
- ☐ Somewhat private
- ☐ Moderately private
- ☐ Very private
- ☐ Extremely private

40. Does this building have ramps, hand rails in toilets and bathrooms and other necessary design features for the elderly and people with disability?

☐ No ☐ Yes

41. Do you think the elevators in this building are large enough to fit in a wheel chair and stretcher?

□ No □ Yes

Part 3: Environmental issues

42. Please assess the overall day-lighting conditions in your apartment
    - □ Poor
    - □ Somewhat good
    - □ Moderately good
    - □ Very good
    - □ Excellent

43. Can you feel air movement in the rooms?
    - □ Very rarely
    - □ Rarely
    - □ Occasionally
    - □ Often
    - □ Very often

44. Please indicate the severity of the following environmental problems in your building:

Environmental problems	Not severe	Somewhat severe	Moderately severe	Very severe	Extremely severe
Water pollution	□	□	□	□	□
Air pollution	□	□	□	□	□
Noise pollution	□	□	□	□	□

45. Please assess how household waste is managed in your building
    - □ Poor
    - □ Fair
    - □ Good
    - □ Very good
    - □ Excellent
    - □ N/A

46. Is there space for common collection of waste in the building?

47. Is the waste in your apartment separately collected so that they can be recycled?

48. Have you heard of separation of household waste in 3 different bins for organic, recyclable and non-recyclable?

49. How is waste collected in your apartment?

50. Do you have any of the following fire safety provisions in your building?
    - □ Enclosed fire stairs
    - □ Open fire-stairs
    - □ Fire exit
    - □ Evacuation layout plan
    - □ Other: Specify_____
    - □ Smoke detector
    - □ Fire alarm
    - □ Fire extinguishers
    - □ Fire drills
    - □ Sprinklers
    - □ Water hydrant
    - □ Fire warden
    - □ Clear signage indicating exit routes

51. How would you rate the fire safety of the building?

□	Poor	□	Very good
□	Fair	□	Excellent
□	Good	□	N/A

52. Please indicate the level of severity of the following resources:

Resources	Not severe	Somewhat severe	Moderately severe	Very severe	Extremely severe
Electricity	□	□	□	□	□
Water	□	□	□	□	□
Gas shortage	□	□	□	□	□

53. How is electricity metered in your unit?

54. How is gas metered in your unit?

55. How is water metered in your unit?

56. Are you aware of water saving techniques?

57. What are the water-saving devices used in your household?

58. Is rain water collected and reused in your building?

Part 4: Behavioural aspects

59. Willingness to have (pay for):

	Very unlikely	Unlikely	Somewhat likely	Likely	Very likely
Fire security measures	□	□	□	□	□
Security measures at the entrance	□	□	□	□	□
Energy efficient lighting system	□	□	□	□	□
Water efficient fixtures and fittings	□	□	□	□	□
Design consideration for the disabled and elderly people	□	□	□	□	□
Elevators, large enough to fit a wheelchair and stretcher	□	□	□	□	□

Playing space for children	◻	◻	◻	◻	◻
Well-designed interactive community spaces	◻	◻	◻	◻	◻
Inspections for maintenance purposes	◻	◻	◻	◻	◻
The provision of gym and game facilities	◻	◻	◻	◻	◻
The provision of more open space	◻	◻	◻	◻	◻
Electrical sub-metering for major consuming devices	◻	◻	◻	◻	◻
Maintain and pay for the provision of roof gardens	◻	◻	◻	◻	◻
Electrical appliances that have energy star ratings	◻	◻	◻	◻	◻
The additional cost for the secondary energy source	◻	◻	◻	◻	◻
Willingness to collect waste in 3 bins	◻	◻	◻	◻	◻
Willingness to use rainwater and gray water	◻	◻	◻	◻	◻

60. How willing are you to undertake educational and training programs on:

Educational and training programs	Very unlikely	Unlikely	Somewhat likely	Likely	Very likely
Fire safety	◻	◻	◻	◻	◻
Emergency preparedness during natural disasters	◻	◻	◻	◻	◻
Efficient electricity management	◻	◻	◻	◻	◻
Efficient water management	◻	◻	◻	◻	◻
Efficient gas management	◻	◻	◻	◻	◻
Efficient household waste management	◻	◻	◻	◻	◻

Appendix C: Household Questionnaire Survey-2 Documents

C-1 Participant information sheet

PARTICIPANT INFORMATION SHEET

HOUSEHOLD QUESTIONNAIRE SURVEY 2

Data Collection: Sustainable High-rise Housing: the Context of Dhaka, Bangladesh

I am a Bangladeshi PhD student at the School of Architecture, Landscape Architecture & Urban Design, University of Adelaide, Australia. My research topic is "Sustainable High-rise Housing: the Context of Dhaka, Bangladesh". This study aims to develop a framework for sustainability in high-rise housing in Dhaka. The framework proposed in this study could be used to set the criteria for sustainability in high-rise housing in Dhaka. In order to create a suitable assessment framework for Dhaka, it is essential to understand the present scenario of residential high-rise living in Dhaka.

Therefore, you are invited to participate in a questionnaire survey to understand the current conditions, problems, constraints of high-rise residential buildings. The survey should take about 15-20 minutes to complete. The findings from the survey will be an integral part of the research, leading to the thesis that will be submitted for the degree of Doctor of Philosophy.

Your participation in this interview survey is completely voluntary. You may withdraw from it whenever you desire by simply advising the researcher of your intention to do so. After the questionnaire is collected, the data obtained will be anonymously code-recorded by the researcher. You will not be identifiable in any way by the collected data as well as in the published results.

The results are confidential and will only be seen by the researcher. You do not need to give your name when completing the survey. The information obtained from the survey will be discussed with the researcher's supervisors, and/or other post-graduate students in the School of Architecture, Landscape Architecture and Urban Design at The University of Adelaide. If you wish, a summary of the interview and questionnaire will be forwarded to you for confirmation of accuracy.

This project has received Ethics Approval from the University's Human Research Ethics Committee. Information about the Independent Complaint Procedure and the role of the Human Ethics committee is provided on a separate sheet.

For any further information, please do not hesitate to contact us:

Assoc. Prof. Dr. Veronica Soebarto (Principal Supervisor)
School of Arch., Landscape Arch. & Urban Design,
The University of Adelaide,
SA 5005, Australia
Ph. 61 8 8303-5695 Fax 61 8 8303-4377
Email: veronica.soebarto@adelaide.edu.au

Tahmina Ahsan (PhD candidate)
Flat A-2, 8/17 Block C, Lalmatia,
Dhaka-1207, Bangladesh
Ph. +61431866320 (Australia), 01767695977 (Bangladesh)
Email: tahmina.ahsan@adelaide.edu.au

I am looking forward to receiving your positive reply and I do appreciate your participation in this research project.

Yours Sincerely,
Tahmina Ahsan

C-2 Consent Form

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

STANDARD CONSENT FORM
FOR PARTICIPANTS (HOUSEHOLDS) IN THE RESEARCH PROJECT

Participant to complete:

1. I ....(please print name) have read the attached Information Sheet and agree to take part in the research project titled : **Sustainable High-rise Housing: the Context of Dhaka, Bangladesh**

2. I acknowledge that I have read the attached '**Participant Information Sheet'**

3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

4. Although I understand the purpose of the research project it has also been explained that involvement may not be of any benefit to me.

5. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

6. I understand that I am free to withdraw from the project at any time and I realize that this project will not affect me now and in the future.

7. I agree to the researcher taking photographs of the interiors and exteriors my house.
   Yes ☐ No ☐

8. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

Signature: .... Date: ....

Witness to complete:

I have described to... (name of subject) the nature of the research to be carried out and in my opinion she/he understood the explanation.

Status in Project: **Researcher-PhD Candidate**

Name: **Tahmina Ahsan**

Signature: .... Date: ....

C-3 Household Questionnaire Survey- 2

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Part 1: Personal characteristics of the respondents

1. Personal specify your personal information

Name (optional):		Floor No	
Address:		Contact No (optional):	

Part 2: Satisfaction of high-rise living

2. Please rank your level of satisfaction of living in this high-rise residential building.

Not satisfied	Somewhat satisfied	Moderately satisfied	Very satisfied	Extremely satisfied
1	**2**	**3**	**4**	**5**

3. Please rank your level of satisfaction for the following social issues of living in high-rise residential buildings by placing a tick (√)

	Not satisfied	Somewhat satisfied	Moderately satisfied	Very satisfied	Extremely satisfied
	1	**2**	**3**	**4**	**5**
Community safety and security					
Availability of neighbourhood facilities					
Regular inspection of structural problems					
Regular inspection of elevators					
Regular inspection of electrical installations					
Regular inspection of fire safety & protection					
Regular inspection of building exterior					
Regular inspection of building interior					
Regular inspection of plumbing systems					
Regular inspection of sewage systems					

4. Please rank your level of satisfaction for the following design issues of your building and apartment by placing a tick (√)

	Not satisfied	Somewhat satisfied	Moderately satisfied	Very satisfied	Extremely satisfied
	1	**2**	**3**	**4**	**5**
Size of bedroom 1					
Size of bedroom 2					
Size of bedroom 3					
Size of bedroom 4					

Size of living room					
Size of dining room					
Size of kitchen					
Size of toilet					
Aesthetic appearance of building					
Room layout plan					
Orientation of rooms					
Interior design					
Efficiency of usable area					
Storage facilities					
Design of kitchen facilities					
Design of bathroom facilities					
Visual privacy					
Setback distance					
Space for interaction with neighbours					
Playing space for children					
Open space around the building					
Design features for the elderly and disabled					
Efficiency of community space					

5. Please rank your level of satisfaction for the following environmental issues in your building and apartment by placing a tick (√)

	Not satisfied	**Somewhat satisfied**	**Moderately satisfied**	**Very satisfied**	**Extremely satisfied**
	1	**2**	**3**	**4**	**5**
Day-lighting in bedrooms					
Day-lighting in living room					
Day-lighting in dining room					
Day-lighting in kitchen					
Natural ventilation in the rooms					
Noise level in the rooms					
Construction quality of the building					
Structural safety of the building					
Household waste management					
Metering systems for electricity usage					
Metering systems for water usage					
Metering systems for gas usage					
Provision of water efficient fixtures					
Provision of storage and reuse of rainwater					
Backup power generation					

Part 3: Concerns of high-rise living

6. Please rank your level of concern for the following issues of living in high-rise residential buildings by placing a tick (√)

	Not concerned	Somewhat concerned	Moderately concerned	Very concerned	Extremely concerned
	1	2	3	4	5
Building height					
Lack of neighbourhood facilities					
Lack of playing space for children					
Lack of visual privacy					
Lack of social interaction					
Who are the neighbours					
Emotional stress or mental health difficulties					
Behavioural problem in children					
Problems in children's development					
Accidental falls of family members					
Leaping from high-rise buildings as suicidal attempts					
Travel time in elevator					
Crime in corridor					
Crime in the elevator					
Elevator breakdown					
Fire risk					
Structural safety					
Power failure					
Water crisis					
Monthly expenses for utility services					
Apartment rent					

Part 4: Importance of having neighbourhood facilities

7. Please rank the importance of having the following neighbourhood facilities in the vicinity of your building by placing a tick (√)

	Not important	Somewhat important	Moderately important	Very important	Extremely important
	1	2	3	4	5
Primary school					
High school					
Park					
Playground					
Mosque/Worship place					
Library					
Doctor's chamber					
Beauty parlour					
Laundry shop					

Hair dresser					
Cyber café/internet service provider					
Photocopy/mobile/land phone/fax service					
Computer based service					
Vehicle repair services					
Post office/courier services					
Rickshaw/ auto-rickshaw stand					
Restaurant, tea bar, fast-food					
Tailoring					
Municipal waste collection points					
Community club including indoor games					
Cultural facilities					
Community police/barrack					
Technician services					
Recreational facilities and community halls					
Supermarket					
Grocery shops					
Pharmacy					
Sweet shop					
Fruit shop					
Flower shop					

Appendix D: Ethics

D-1 Human Research Ethics application form

THE UNIVERSITY of ADELAIDE

Office use only	
Received:	
Application No:	
Ethics Approval No:	

Human Research Ethics Committee (HREC)
2012 Application for low risk review of research involving people

SECTION 1: APPLICANT, OTHER RESEARCHERS AND PROJECT SUMMARY DETAILS

If the project is to be undertaken by a research student the student's primary or other supervisor at the University of Adelaide is the 'applicant'.

Applicant's name, title and position:	Associate Professor Veronica Soebarto, PhD		
Telephone:	+61 8 8313 5695	**EMPLID:**	
Department:	School of Architecture, Landscape Architecture and Urban Design	**Campus and Institution address:**	North Terrace, The University of Adelaide, Australia 5005
Email:	veronica.soebarto@adelaide.edu.au		
Qualifications and relevant research experience	Dr Soebarto has conducted thermal and other environmental monitoring studies of buildings for more than 15 years. She has published her work in more than 50 papers/journal articles/book chapters. She has supervised 25 research students (14 PhD, 2 Masters and 12 Honours) in the past 14 years.		

Student's name, title:	Tahmina Ahsan	**Student ID:**	a1615606
Program Level:	PhD	**Department** (if not same as Principal Researcher's)	
Email:	tahmina.ahsan@adelaide.edu.au		
Qualifications and relevant research experience	Bachelor of Architecture (Ahsanullah University of Science and Technology, 2002) Master's in Environmental Engineering and Sustainable Infrastructure (KTH, Royal Institute of Technology, 2009) Previous publication that employed research techniques that will be used in this study: Ahsan, T and Svane, O. (2010).Energy Efficient Design Features for Residential Buildings in Tropical Climates: The Context of Dhaka, Bangladesh. Conference Proceedings of Sustainable Architecture and Urban Development. Vol- 4. pp. 183-202.		

Other researcher(s) name(s), title(s) and position(s)		**EMPLID(s)** (if applicable)	
Qualifications and relevant research experience			

Project title:
Sustainable High-rise Housing: the Context of Dhaka, Bangladesh

Location of the research:
Dhaka, Bangladesh

Proposed commencement date of project:
21-07-2012

Estimated duration or completion date of the project:
21-08-2013

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Source of project funding:

RAS (Research Abroad Scholarship) for field trip

Has or will this project be submitted for approval to other HRECs? Include the HREC's name and current status of the application (i.e. submitted, approved, deferred or rejected)

NO

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SECTION 2: NATURE OF THE PROJECT

Aims of the project: (discuss in lay terms; include the research hypothesis to be investigated, outline the values and benefits to participants)

This study aims to develop a framework for sustainability in high-rise residential buildings in Dhaka. At present there is an absence of any kind of clear and verifiable assessment measures for sustainability in high-rise residential buildings in Dhaka. The purpose of this study is to set the criteria for sustainability in high-rise residential buildings in Dhaka as well as to identify the indicators that may be used to analyse the sustainability of a high-rise residential building in Dhaka. Finally, this study will demonstrate how building evaluations against appropriately selected sustainability indicators can play an important role in improving the quality of, and achieving sustainability in, high-rise buildings in Dhaka.

Rationale of the project: (explain in simple language the research methodology and its appropriateness to achieving the aims and provide evidence of an adequate sample size to establish a valid result)

The research will be conducted using through two types of field study. The first one would involve interviews of occupants of high-rise and field surveys of about 50-100 households with semi-structured questions to evaluate the present scenario of sustainability in high-rise residential buildings in Dhaka. The second one would involve investigating how relevant stakeholders view sustainability, their current problems, challenges and aspirations to promote sustainable high-rise residential buildings. It would also investigate how an assessment framework for high-rise residential building could be made an acceptable and integral part of the building practice in Dhaka. The specific questions targeted to each stakeholder group will be formulated based on the set of indicators identified through extensive literature review. The sustainability indicators will then be presented to the stakeholders in the form of a semi-structured questionnaire. The workshop will enable a discussion on the sustainability indicators that has been prepared for the context of Dhaka and feedback from the stakeholders will be noted in order to outline the framework for sustainable high-rise residential buildings.

Background to the project: (discuss any previous research of relevance and include references)

N/A

Have there been any preliminary studies, if Yes, provide the project title and HREC approval number(s):

No

Outline the study plan and design, giving a detailed description of all planned interactions between researchers and participants. *Attach copies of surveys, interview or focus group schedules, questions, and topics to be covered.*

The study plan and design has already been outlined under the section: Rationale of the project.

If research is to be conducted overseas; outline any local legislation, regulations, permissions or customs that need to be addressed before the research can commence. Outline the steps taken to ensure that this area has been adequately addressed in your proposal? *Attach* *authorizing correspondence, approval documentation to the application.*

This research will be conducted in Bangladesh, the researcher's home country. Recruitments of participants can be done directly without requiring permissions from local authorities.

SECTION 3: PARTICIPANTS AND RECRUITMENT

Who are the participants in this project? Include the source, number and age of all participants and outline how this sample will allow the aims of the project to be achieved.

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Participants in this project can be categorized in the following ways:
Type 1 A-Occupants of high-rise residential buildings in Dhaka who are more than 18 years old.
Type 1 B-Respondents to an online questionnaire who then agree to take part in the field study (to be surveyed).
Type 2- Stakeholders of high-rise buildings. The stakeholders would comprise participants of the following professions:
Architects
Real Estate Developers
Contractors
Construction Engineers
Structural Engineers
Planners
Policy-makers

Outline the participant selection and exclusion criteria (include how and by whom the screening will be conducted):

Occupants of households in high-rise residential buildings will be randomly selected by real estate developers, architects and care-takers of the high-rises who will be conducted by the researcher. The screening will be conducted by the researcher based on the willingness of the participants.

For the Focus Group workshop, the participants (stakeholders) such as members of the Institute of Architects, the Institute of Urban Planners, the Institute of Engineers and the Real Estate Housing Association of Bangladesh will be contacted through their organisations and willing participants will be randomly selected.

How will participants be recruited? Explain each of the following areas in detail:

- *How you will recruit volunteers onto the study. How will people be approached and asked if they are willing to participate? How and by whom will personal information including names and contact details be accessed?*
- *What materials will be used? (Attach any advertisements, flyers, emails, Facebook pages, other.)*

For the selection of participants in the Type 1 category the following methods would be undertaken:

1. Real estate developers and architects would be contacted and the Participant Information Sheet would be handed out to them so that they can hand it out to the clients who purchased flats in high-rise residential buildings designed by those developers and architects. High-rise building occupants who would be willing to participate in the research would be asked to contact the researcher.

2. High-rise residential building care-takers will be given flyers to be distributed to the occupants. The flyers will contain information of the survey and the contact details of the researcher.

3. An online survey of occupants of high-rise residential buildings will also be conducted using Survey Monkey which will be published in the researcher's Facebook page. The researcher will not necessarily survey their houses unless they are willing to be visited.

For the Focus Group survey in the Type 2 category, various institutes like the Institute of Architects, the Institute of Urban Planners, the Institute of Engineers and the Real Estate Housing Association of Bangladesh would be contacted and willing participants will be randomly selected.

Outline the specific tasks that participants will be asked to undertake including approximate time involved?

The high-rise residential building occupants would be given a questionnaire that would take about 30 minutes to complete. The discussion with the Focus Group would take approximately two hours. This would include an open discussion and a questionnaire that would need to be filled out.

If recruitment is to be conducted by a third party or another organisation, outline how this will be done?

N/A

Describe any possible risks to the health or safety of the researcher(s) when undertaking the research?
Note: where interviews are to be held in participants' homes as opposed to public places provide a rationale for why this is necessary and outline the personal safety protocol for the researchers involved:

The survey of the households of the high-rise residential buildings would be done in their respective homes firstly to be able to record the existing scenario of high-rise residential buildings in Dhaka and second, because of the participant's convenience. Even though this survey is considered low-risk, the researcher will be accompanied by her colleague to ensure personal safety. The focus group discussion will be held in the researchers home university where there is no safety concern.

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SECTION 4: ETHICAL CONSIDERATIONS

Provide a detailed description of all potential risks and benefits to participants (including physical, emotional, social or legal) and steps to address these risks:

There will be no manipulation or experiments on the subject, therefore, this is a low risk research project. It is presumed that there will be no foreseeable risks to participants

Is there a protocol that will be followed in the event of any adverse events? Note: an adverse event can include situations where participants may decide to withdraw themselves or their information during/after an interview or focus group. ***Attach a copy of the protocol to the application.***

It has been mentioned in the Information Sheet and in the Standard Consent Form that participation in this project is voluntary and the participants can withdraw from the project at any time.

Will participants receive any reimbursement of out of pocket expenses, or financial or other rewards as a result of participation? What is the amount or nature of the reward and the justification for this?

The participants using the web link of Survey Monkey will have the opportunity to win a $10 shopping voucher (through a lottery system) when they take part in the survey as Type 1B participants. The justification for this reward is to avoid fake data given through the online survey.

Will a written Information Sheet be provided to all participants? Explain how and when? ***Attach this document to the application.***

An Information Sheet for all participants would be distributed to the participants before the survey .

How and when will written consent be obtained? ***Attach this document to the application.***

Consent Form will be given to the participants at the beginning of the survey

For participants not fluent in English or who have difficulty understanding English, what arrangements will be made to ensure comprehension of the Information Sheet and Consent Form?

The researcher will translate any terms that the participants have difficulty in understanding.

SECTION 5: PROTECTION OF PRIVACY AND CONFIDENTIALITY OF INFORMATION

Which of the following statements apply to the research:

- ☐ **Complete anonymity of participants?** (i.e. researchers will not know the identity of participants as the participants are part of a random sample and are required to return responses with no form of personal identification)
- ☐ **Non-identified samples or data?** (i.e. an irreversible process whereby identifiers are removed from data and replaced by a code, with no record retained of how the code relates to the identifiers. It is then impossible to identify the individual to whom the sample of information relates)
- ☒ **Re-identifiable samples or data?** (i.e. a reversible process in which the identifiers are removed and replaced by a code. Those handling the data subsequently do so using the code. If necessary, it is possible to link the code to the original identifiers and identify the individual to whom the sample or information relates)
- ☐ **Participants have the option of being identified in any publication arising from the research?**
- ☒ **Participants are referred to by a pseudonym in any publication arising from the research?**
- ☐ **Other methods of protecting the privacy of participants?** *(please describe below)*

Will researchers be taking photographs or recordings of participants using audio tape, film/video, or other electronic medium and how are these to be used?

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As part of a qualitative survey, the researcher will be taking photographs of the flats in the high-rise residential buildings without the occupants unless they are willing to be photographed. The focus group discussions would be audio taped to ensure accuracy in data collected.

How will the confidentiality of the data collected/disseminated, including the identity of participants, be assured? Where the sample size is very small, it may be impossible to guarantee anonymity/confidentiality of participant identity. Participants involved in such projects need to be clearly advised of this limitation in the *Information Sheet*.

The data obtained after the survey will be coded by the researcher. The identity of the participants in the focus group discussion will not be disclosed in any form of publication.

SECTION 6: DATA ANALYSIS AND STORAGE

How is the information (data) to be analyzed, and who will have access?

The data will most likely be analyzed using software like Excel and NVivo. The researcher, the principal supervisor and the co-supervisor will have access to the data.

Will participants receive feedback of findings prior to any publication (including access to transcripts of interviews or drafts of reports)?

It has been mentioned in the Information Sheet that a summary of the interview and questionnaire would be forwarded to the participants (focus group) if they wish to receive one.

Will the project outcomes be made publicly accessible at the end of the project and in what forms (e.g. journal article, book, conference paper, the Media)?

The project outcomes may be made publicly accessible at the end of the project in the form of journal article and conference paper.

Outline the methods to be used for the storage, location, and access to, all records and materials (written or electronic) that have been used/collected during and after completion of the project.

The soft copy of the records and materials will be retained in the researchers computer and password protected external hard-drive and the hard copy would be retained in the researcher's filing cabinet for 5 years from the date of any publication

Outline the length of time that the records and materials will be retained by the University. (Note that the minimum period for retention of research data is 5 years from the date of any publication and varies depending on the specific type of research. For more information refer to Section 2.1 of the Australian Code for the Responsible Conduct of Research at http://www.nhmrc.gov.au/guidelines/publications/r39)

The records and materials will be retained for 5 years from the date of any publication.

SECTION 7: CONFLICT OF INTEREST OR OTHER ETHICAL ISSUES

Outline any 'conflict of interest' issues that may arise during the project?

None

Do the researchers expect to obtain any direct or indirect financial or other benefits from conducting this research? (Note that such benefits must be declared to the HREC and included in the *Information Sheet*.)

None

Outline any other ethical or relevant issues not discussed in this application:

None

SECTION 8: DECLARATION BY THE RESEARCHERS

Declaration by the researcher(s)

I/we have read the *National Statement on Ethical Conduct in Human Research (2007)*.

I/we, the researcher(s) agree to:

- start this research project only after obtaining final approval from the Human Research Ethics Committee (HREC)

HREC_Low_Risk_Review_Application_Form_V1-6.doc

- only carry out this research project where adequate funding and personnel is available to enable the project to be carried out according to good research practice and in an ethical manner
- notify the HREC in writing in the event of any adverse or unforeseen events; amendments; completion; discontinuation of the project or changes to research personnel
- provide an annual progress report to the HREC for the duration of the research project;
- apply for annual renewal (noting approval is only given for a period up to 12 months)
- provide the HREC with a final report
- agree to participate in an audit if requested by the HREC.

In addition, as the applicant, I:

- accept responsibility for the conduct of this research project according to the *National Statement on Ethical Conduct in Human Research (2007)*
- certify that all researchers and other personnel involved in this project are appropriately qualified and experienced or will undergo appropriate training and supervision to fulfil their role in this project
- will take responsibility for the confidential maintenance of the data as per the University's Responsible Conduct of Research Policy and as required by legislation.

Applicant's signature:		Name:	Associate Professor Veronica Soebarto	Date:	04-07-2012
Researcher's signature:		Name:	Tahmina Ahsan	Date:	04-07-2012
Researcher's signature:		Name:		Date:	

SECTION 9: CHECKLIST

The following documents are attached to this application:

Yes	No	N/A*	
☒	☐	☐	Participant Information Sheet
☒	☐	☐	Standard Consent Form for a participant in a research project
☐	☐	☒	Third Party to Participation Form required where participants are children under 18 years or a dependent adult
☒	☐	☐	Contacts and Independent Complaints Sheet
☒	☐	☐	Survey instrument/Questionnaire
☒	☐	☐	Procedure/protocol for interviews or focus groups including topics and questions
☒	☐	☐	Recruitment advertisement, flyers, recruitment letter
☐	☐	☒	Adverse event procedure/interview protocol
☐	☐	☒	Evidence of approval/rejection by other HRECs, including comments and requested alterations to the application
☐	☐	☒	Overseas research only: Evidence of permissions, approvals from overseas authorities etc

*Not applicable

HREC_Low_Risk_Review_Application_Form_V1-6.doc

D-2 Contacts and Independent Complaints Sheet

THE UNIVERSITY of ADELAIDE

The University of Adelaide
Human Research Ethics Committee (HREC)

This document is for people who are participants in a research project.

CONTACTS FOR INFORMATION ON PROJECT AND INDEPENDENT COMPLAINTS PROCEDURE

The Human Research Ethics Committee monitors all the research projects which it has approved. The committee considers it important that people participating in approved projects have an independent and confidential reporting mechanism which they can use if they have any worries or complaints about that research.

The following study has been reviewed and approved by the University of Adelaide Human Research Ethics Committee:

Project Title: **Sustainable High-rise Housing: the Context of Dhaka, Bangladesh**

1. If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the project co-ordinator:

Name: **Associate Professor Dr Veronica Soebarto** **Telephone:** **+61 8 8303-5695**

2. If you wish to discuss with an independent person matters related to:
   - making a complaint, or
   - raising concerns on the conduct of the project, or
   - the University policy on research involving human participants, or
   - your rights as a participant,

contact the Human Research Ethics Committee's Secretariat on phone +61 88303 6028.

D-3 Human Research Ethics approval letter

THE UNIVERSITY of ADELAIDE

RESEARCH BRANCH
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY

BEVERLEY DOBBS
EXECUTIVE OFFICER
LOW RISK HUMAN RESEARCH ETHICS REVIEW GROUP (FACULTY OF HUMANITIES AND SOCIAL SCIENCES AND FACULTY OF THE PROFESSIONS)
THE UNIVERSITY OF ADELAIDE
SA 5005
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TELEPHONE +61 8 8313 4725
FACSIMILE +61 8 8313 7325
email: beverley.dobbs@adelaide.edu.au

24 July 2012

Associate Professor V Soebarto
School of Architecture, Landscape Architecture and Urban Design

Dear Associate Professor Soebarto

ETHICS APPROVAL No: HP-2012-045
PROJECT TITLE: Sustainable high-rise housing: the context of Dhaka, Bangladesh

I write to advise that the Low Risk Human Research Ethics Review Group (Faculty of Humanities and Social Sciences and Faculty of the Professions) has approved the above project. The ethics expiry date for this project is **31 July 2015**.

Ethics approval is granted for three years subject to satisfactory annual progress and completion reporting. The form titled *Project Status Report* is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/ethics/human/guidelines/reporting. On expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the Information Sheet and the signed Consent Form to retain. It is also a condition of approval that you **immediately report** anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol; and
- the project is discontinued before the expected date of completion.

Please refer to the following ethics approval document for any additional conditions that may apply to this project.

Yours sincerely

ASSOCIATE PROFESSOR RACHEL A. ANKENY
Convenor
Low Risk Human Research Ethics Review Group (Faculty of Humanities and Social Sciences and Faculty of the Professions)

THE UNIVERSITY of ADELAIDE

RESEARCH BRANCH
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY

BEVERLEY DOBBS
EXECUTIVE OFFICER
LOW RISK HUMAN RESEARCH ETHICS REVIEW GROUP (FACULTY OF HUMANITIES AND SOCIAL SCIENCES AND FACULTY OF THE PROFESSIONS)
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AUSTRALIA
TELEPHONE +61 8 8313 4725
FACSIMILE +61 8 8313 7325
email: beverley.dobbs@adelaide.edu.au

Applicant:	Associate Professor V Soebarto
School:	Architecture, Landscape Architecture and Urban Design
Application/RM No:	13744
Project Title:	**Sustainable high-rise housing: the context of Dhaka, Bangladesh**

Low Risk Human Research Ethics Review Group (Faculty of Humanities and Social Sciences and Faculty of the Professions)

ETHICS APPROVAL No: HP-2012-045

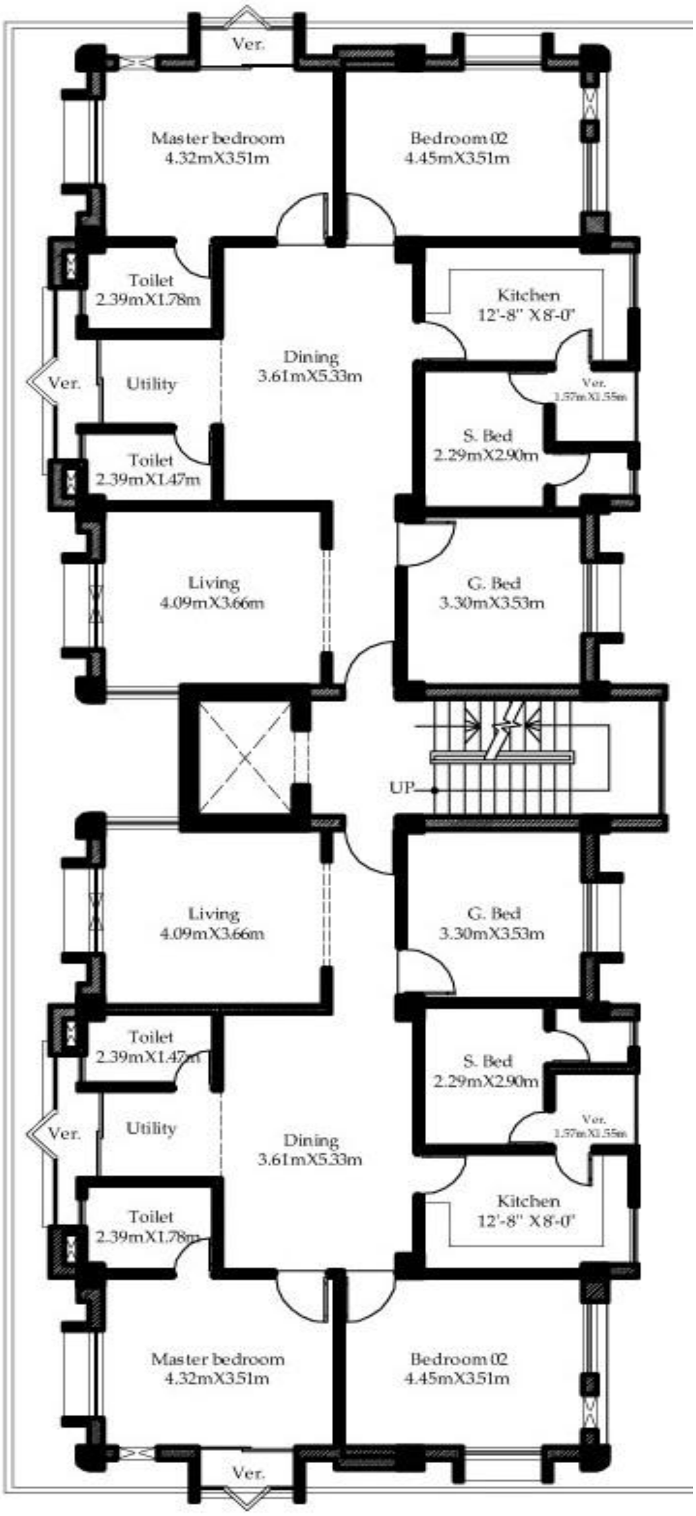
APPROVED for the period until: 31 July 2015

This study is to be conducted by Ms Tahmina Ahsan, PhD Candidate.

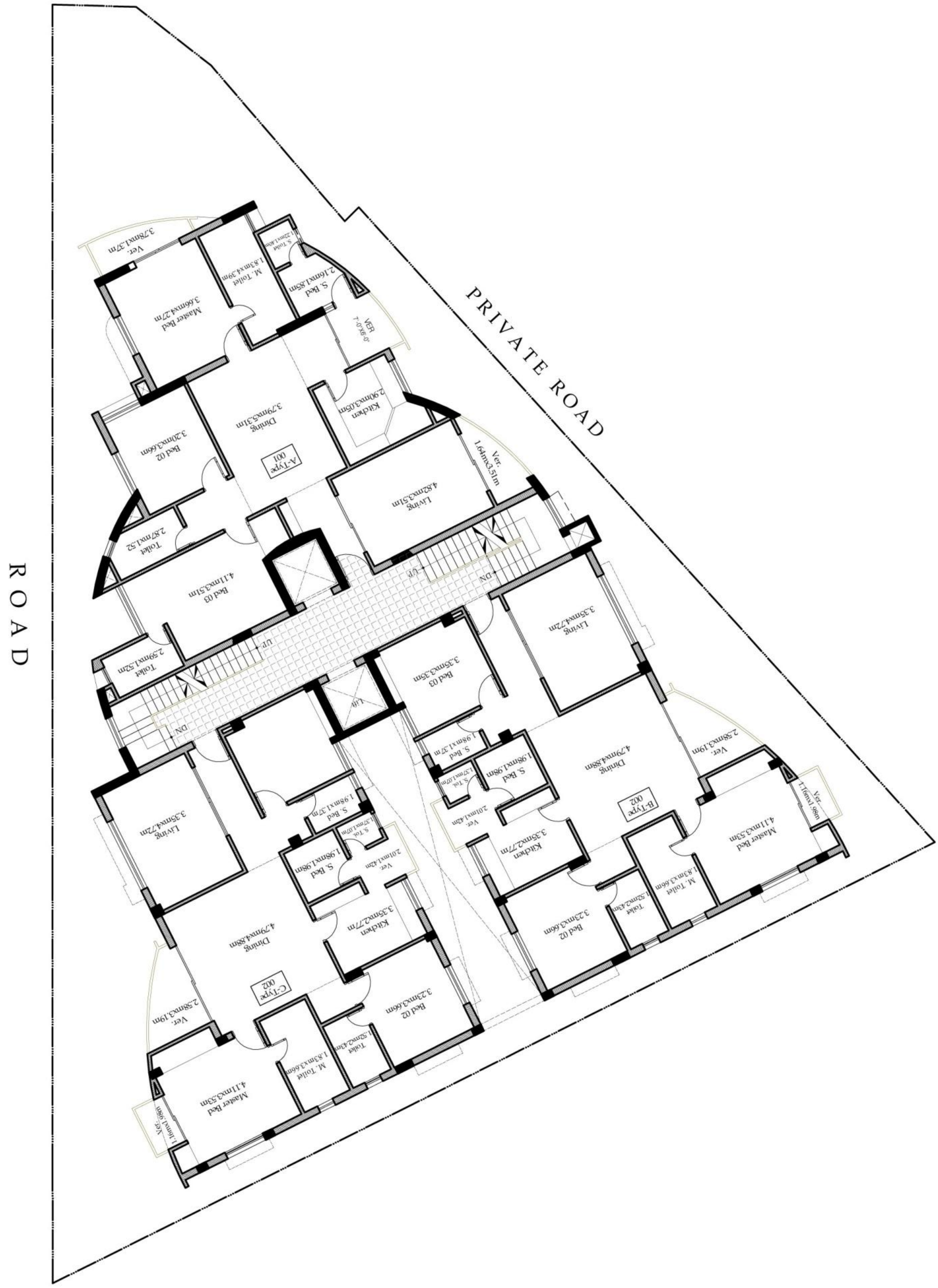
ASSOCIATE PROFESSOR RACHEL A. ANKENY
Convenor
Low Risk Human Research Ethics Review Group (Faculty of Humanities and Social Sciences and Faculty of the Professions)

Appendix E: Floor plans of high-rise residential buildings

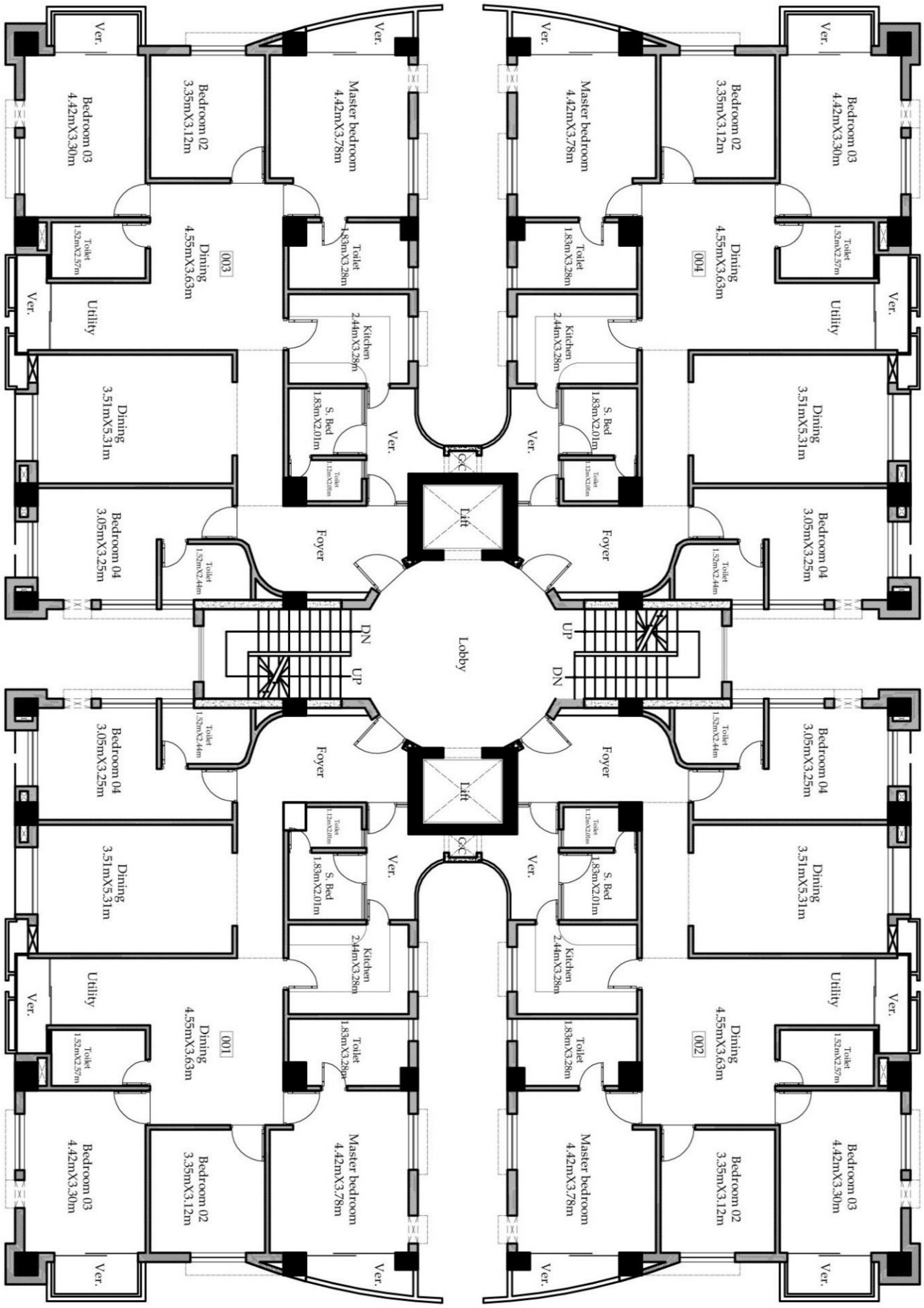
E-1: Floor plan with two apartments



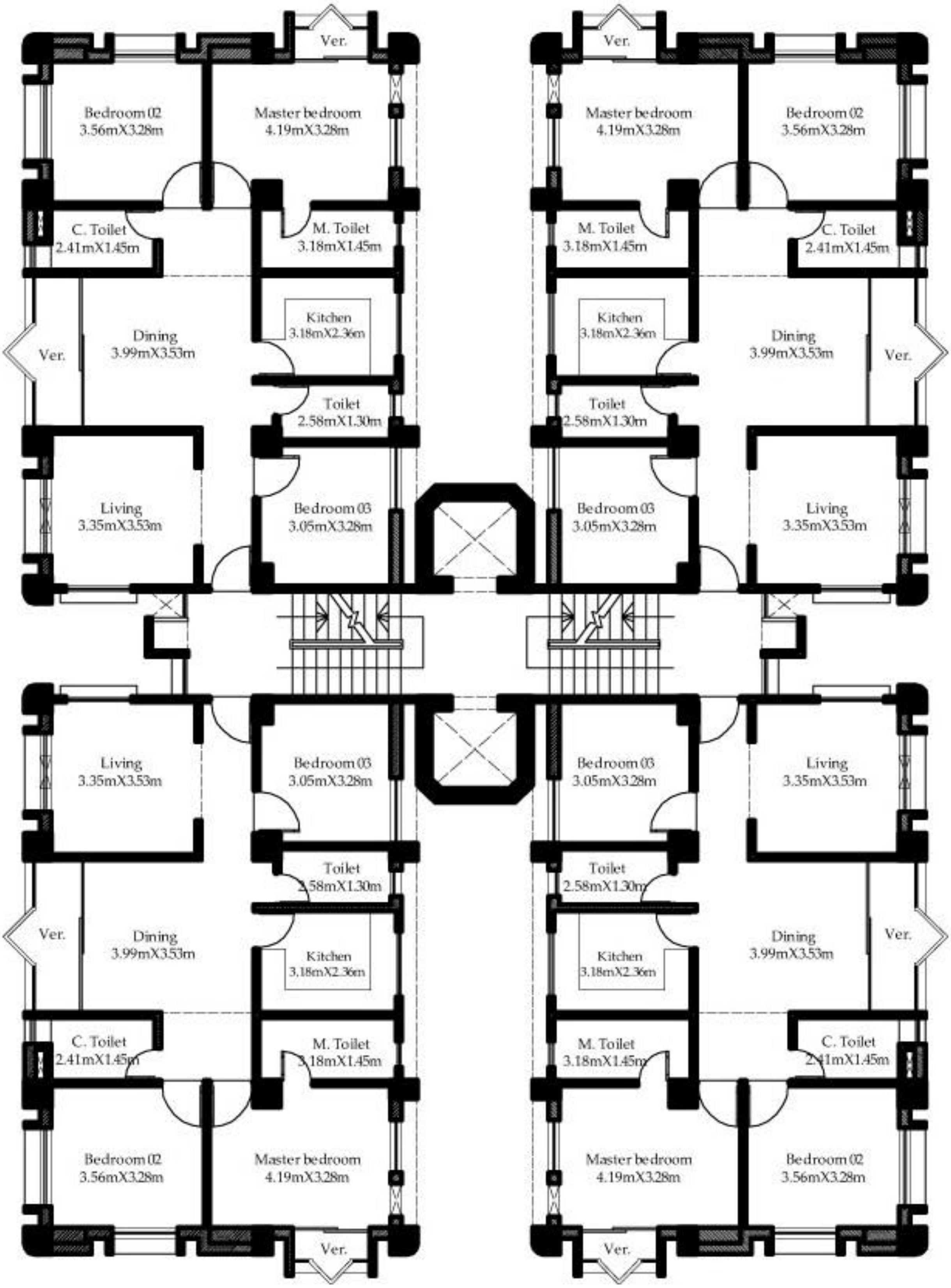
E-2: Floor plan with three apartments



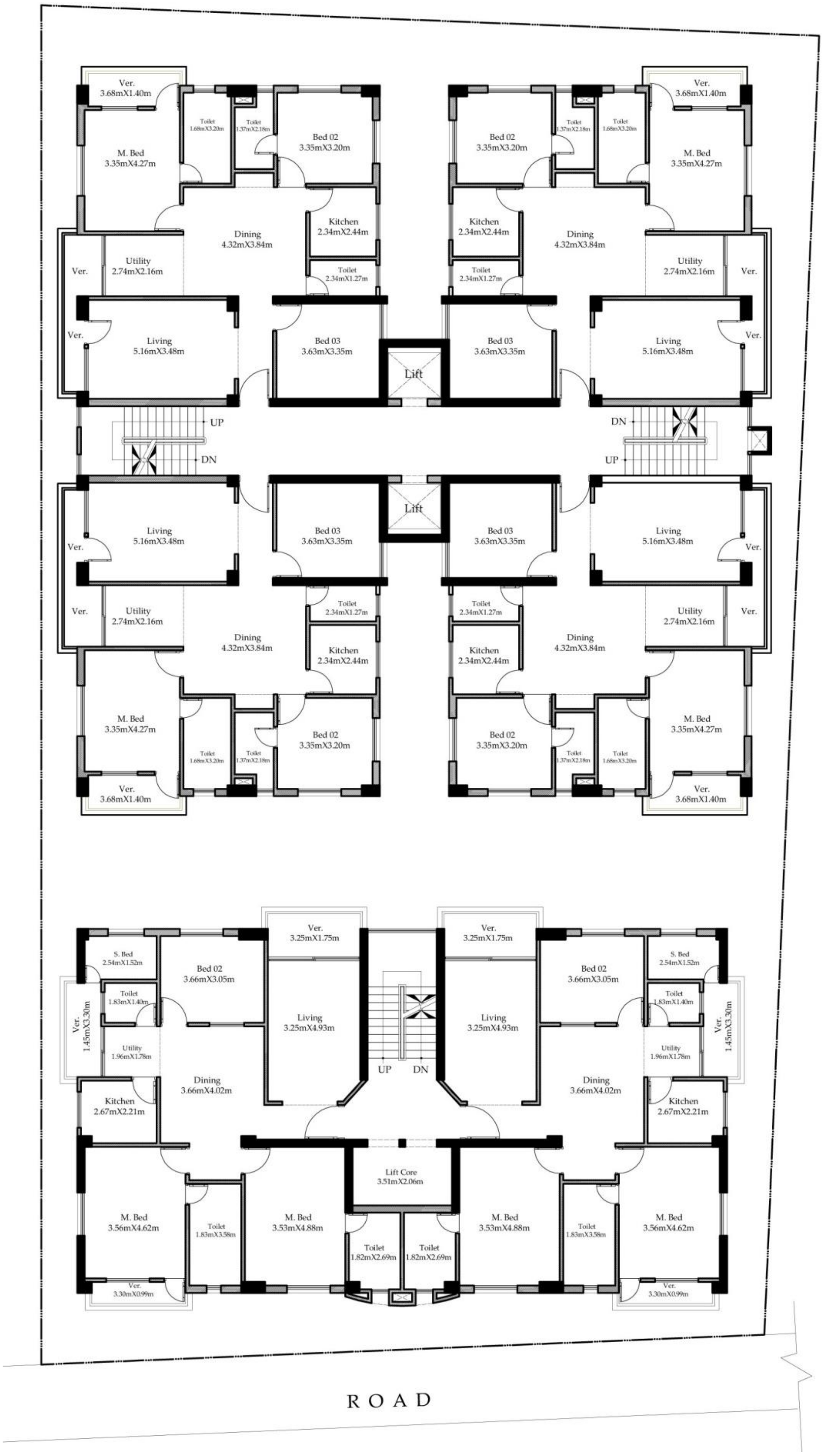
E-3: Floor plan with four apartments



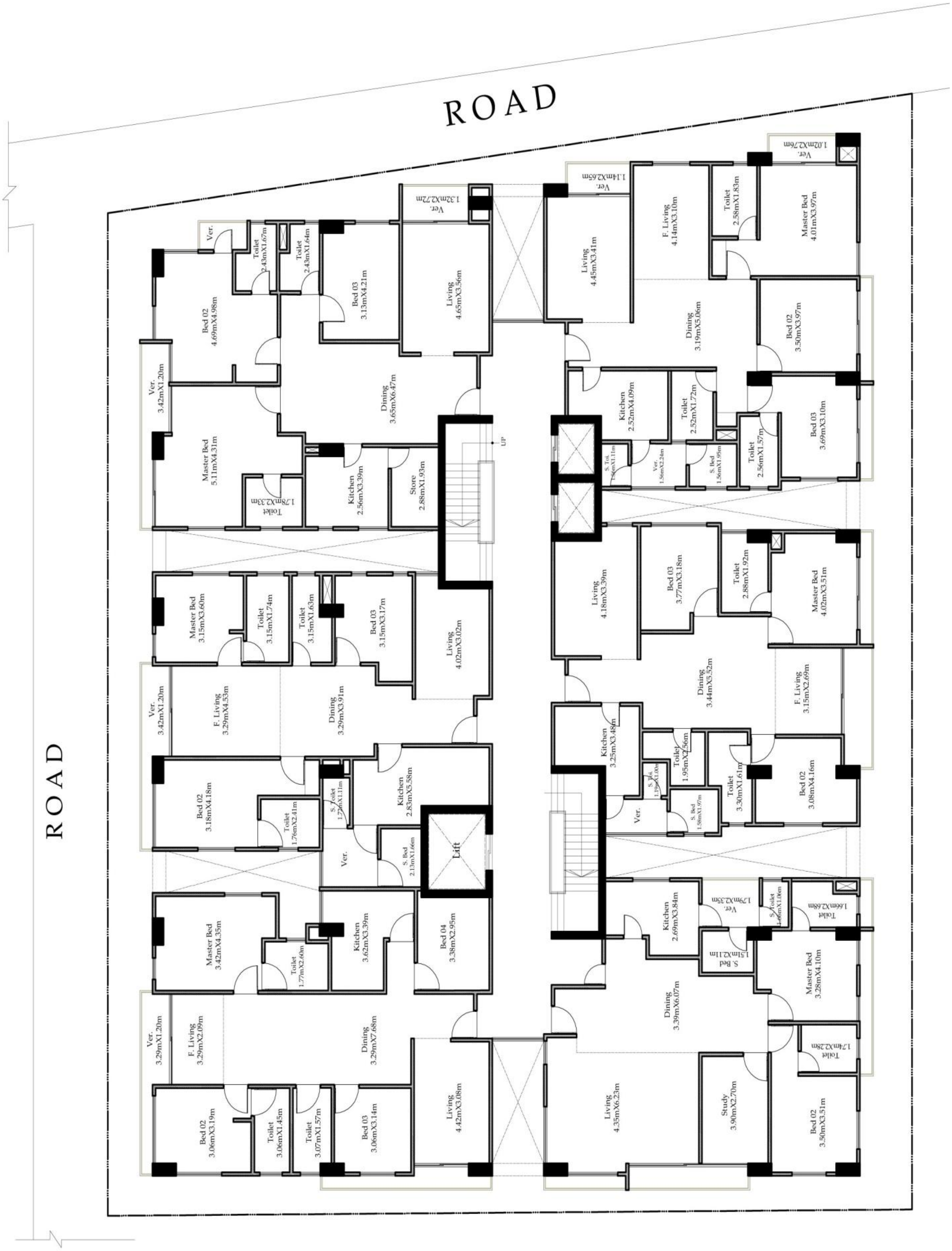
E-4: Floor plan with four apartments



E-5: Apartment complex with two buildings (four apartments in one and two apartments in the other)

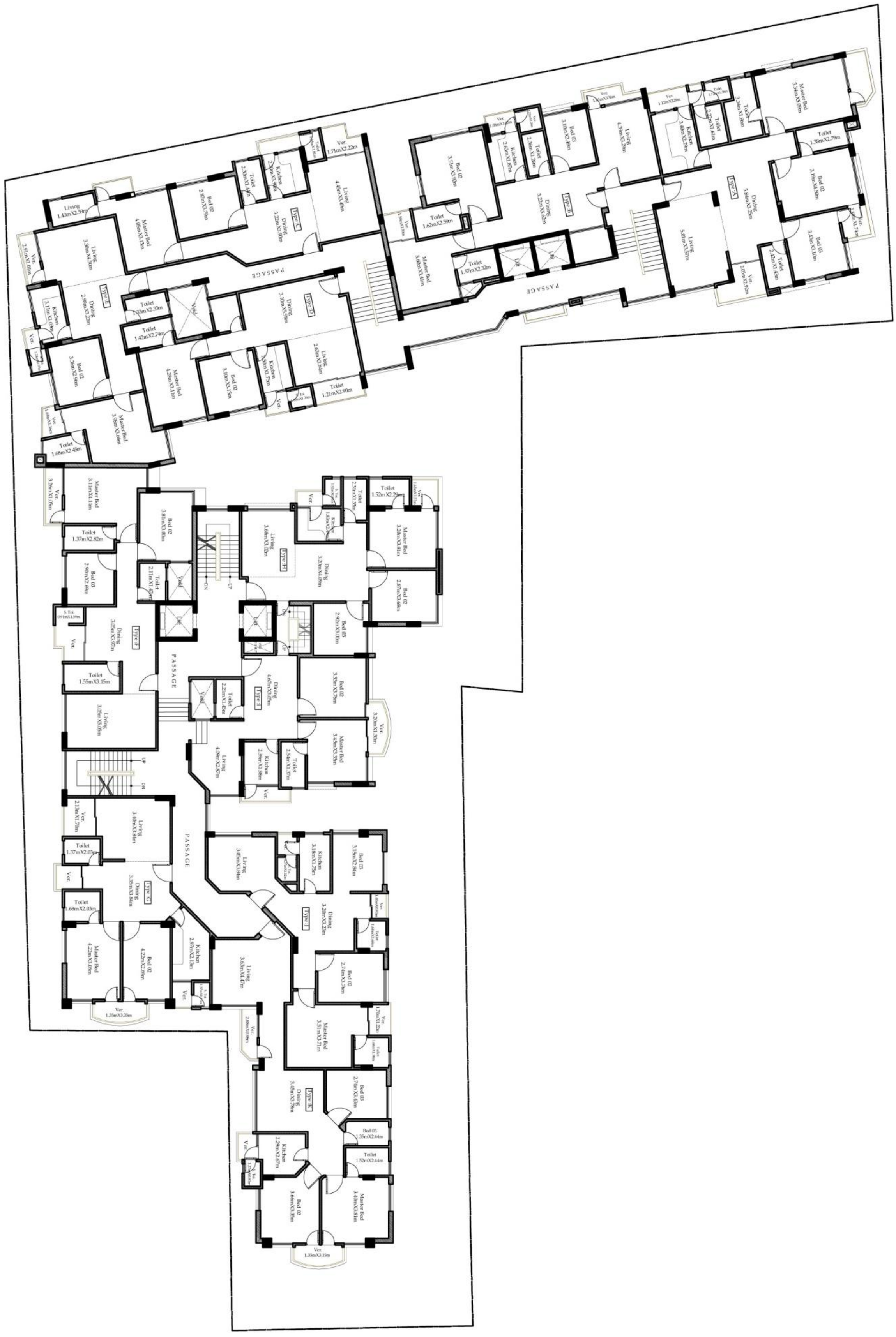


E-6: Floor plan with six apartments

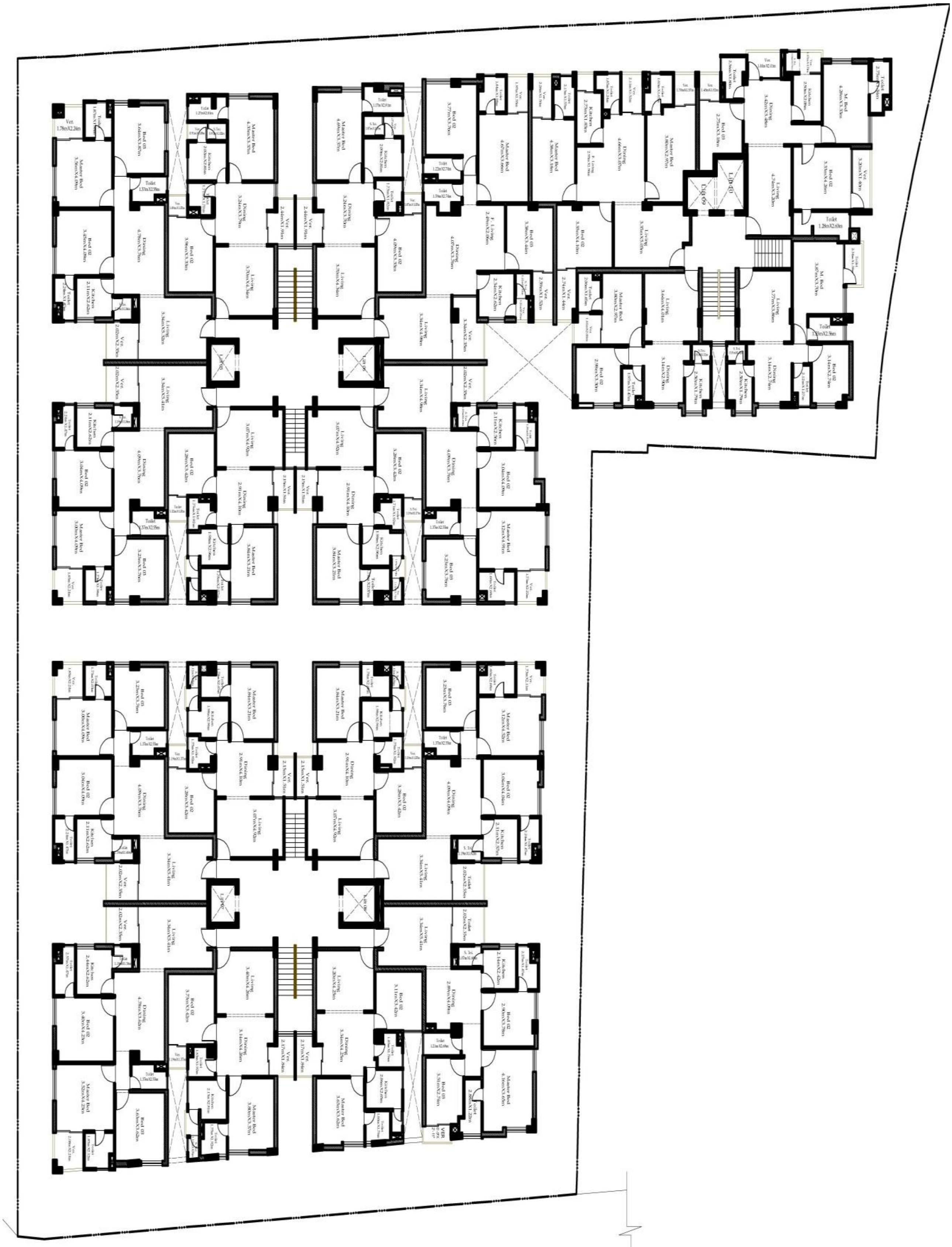


E-7: Floor plan with six apartments

E-8: Floor plan with eleven apartments



E-9: Floor plan with twenty apartments



Appendix F: Draft strategies

Social strategies

Culture and heritage

Objective 1: To ensure that the buildings are culturally acceptable

Strategy 1: Local cultural values should be considered.

Strategy 2: Design of buildings should relate with the existing streetscape.

Objective 2: To ensure the conservation of heritage values

Strategy 1: The heritage value at the urban level should be maintained.

Local people and employment

Objective 1: To ensure local employment in building construction

Strategy 1: Experienced and local design team should be consulted for the design of the buildings.

Strategy 2: Experienced and local contractors should be consulted for the construction of the buildings

Strategy 3: Experienced and local construction workers should be used for the construction of the buildings

Socially responsive design

Objective 1: To ensure that the occupants' needs and priorities are fulfilled

Strategy 1: The users (building occupants) should interact with the design team during the concept and design development phase to ensure that their needs are fulfilled.

Strategy 2: Interdisciplinary work among the involved groups should take place from the beginning of the design process.

Objective 2: To promote the functionality, usability, flexibility and efficiency of the apartments

Strategy 1: The spaces in the apartments should be planned for maximum flexibility.

Strategy 2: The size of the second bedroom should not be less than 11.7)square metres, while the size of third bedroom should not be less than 11.1 square metres.

Strategy 3: The size of the living room should not be less than 12.7 square metres.

Strategy 4: The size of the dining room should not be less than 13.6 square metres.

Strategy 5: Each apartment must be provided with a minimum of 1.5 square metres of storage room.

Objective 3: To ensure playing space for children, space for social interaction and greenery

Strategy 1: The open space in front of a building should be at least 50% of the entire site.

Objective 4: To enhance social interaction amongst the building occupants

Strategy 1: Roof top can be used as spaces for interaction and outdoor recreation areas.

Strategy 2: The lobby needs to be well lit and naturally ventilated to enhance interaction amongst the occupants.

Strategy 3: Well-designed interactive community spaces, in addition to the community halls, must be provided.

Strategy 4: Consideration should be given to gyms with indoor game facilities.

Objective 5: To give due attention to visual privacy, including views to and from windows and balconies in the high-rise residential building from buildings immediately next

Strategy 1: Impacts on visual privacy from adjacent buildings need to be minimised.

Strategy 2: The setback distance between adjacent buildings on different sites needs to increase to at least 7.3 metres (from the current practice of 6 metres) where windows and balconies are present. In case of two buildings on one site, the setback distance should be at least 2.5 metres (the current practice) only if there is no window and balcony. If there are balconies and windows, they should be either diagonally located without facing each other, or the sill and lintel height of the windows on the two buildings should be different from each other.

Objective 6: To ensure design features for the elderly and disabled

Strategy 1: The building and the apartments should have the necessary design features such as ramps with the required slope according to the standards specified in the BNBC, handrails in toilets and bathrooms for the elderly and disabled.

Strategy 2: Elevators should be capable of fitting a stretcher.

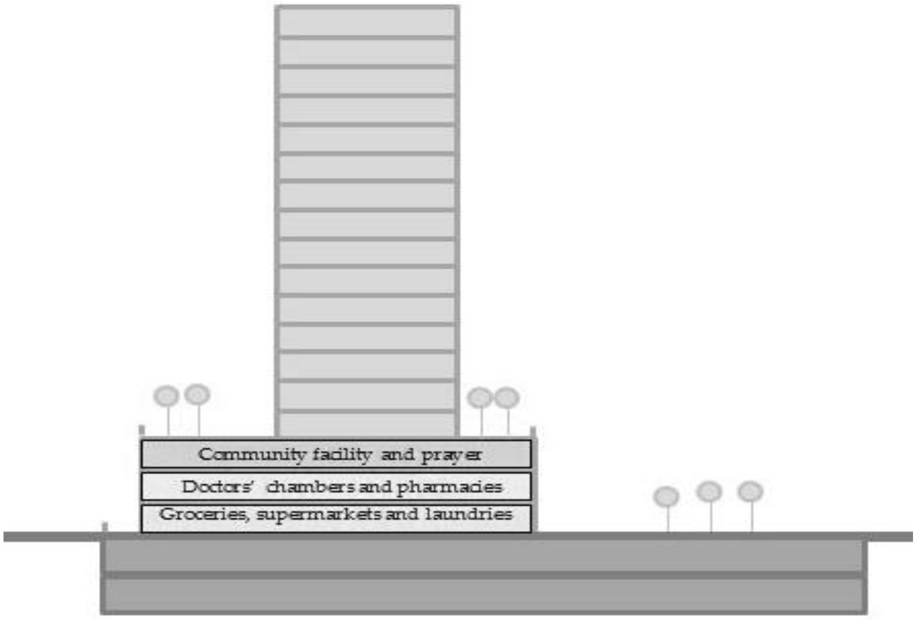
Objective 7: To ensure affordability

Strategy 1: Apartments should be designed with variation in sizes.

Objective 8: To ensure that the neighbourhood has the facilities and amenities that occupants prioritize according to their needs in order to achieve an improved living environment.

Strategy 1: Supermarket, pharmacy/medicine store, grocery shops, rickshaw/ auto-rickshaw stand, mosque/worship place, playground, doctor's chamber, waste transfer station, technician services, park and laundry all need to be present in the neighbourhoods of high-rise residential buildings.

Strategy 2: Some of the facilities mentioned in Strategy 1 (supermarket, pharmacy/medicine store, grocery shops, mosque/worship place, doctor's chamber and laundry) could be accommodated on the lower levels of the buildings.



Objective 9: To ensure safety and security in private and public spaces within the building

Strategy 1: Effective community safety and security measures such as security guards in the building entrance to control unauthorised entry and close circuit cameras in the common spaces (corridors, staircases and lift lobby) must be employed and maintained to make the occupants feel safer.

Strategy 2: Burglar alarms should be deployed in all apartments of the buildings.

Objective 10: To ensure safety of children

Strategy 1: Particular attention should be given to safety for children on balconies and roofs.

Maintenance

Objective 1: To ensure regular maintenance of all building services, features and measures

Strategy 1: The building authority should include a maintenance program with regular periodic inspections of building services.

Strategy 2: All building services, particularly fire-fighting facilities and elevators needs regular maintenance.

Strategy 3: All the buildings should have a long-term maintenance plan.

Strategy 4: Training of building operations staff should be made mandatory

Objective 2: To ensure emergency preparedness planning

Strategy 1: Emergency planning procedures should be part of the maintenance program.

Awareness and education

Objective 1: To promote resource efficiency in buildings

Strategy 1: Effective public awareness programs on resource efficiency should be provided by the government on a macro scale and by the building management on a micro scale to increase the occupants' awareness of electricity, water and gas usage.

Strategy 2: The occupants should be encouraged by the government and the building management to participate in education and training programs on using resources efficiently.

Strategy 3: The government should facilitate the development of curriculums for schools about resource efficiency.

Objective 2: To promote awareness on fire safety amongst the building occupants

Strategy 1: The occupants should be encouraged by the government and the building management to participate in education and training programs on fire safety.

Objective 3: To promote awareness on the effect of hazards such as natural disasters amongst the building occupants

Strategy 1: The occupants should be encouraged by the government and the building management to participate in education and training programs on emergency preparedness planning for natural disasters.

Objective 4: To ensure awareness of the occupants on waste disposal and recycling

Strategy 1: The occupants should be encouraged by the government and the building management to participate in education and training programs in efficient household management (3 bins).

Objective 5: To ensure that the concerned stakeholders of the building construction industry are aware of sustainable building principles.

Strategy 1: Sustainable building principles should be made part of the training courses and accreditation for architects, planners, construction engineers and real estate developers.

Environmental strategies

Site selection

Objective 1: To ensure appropriate selection of land in terms of the environmental consequences

Strategy 1: Any new development should be preceded by flood risk assessments of the site.

Strategy 2: Any new development should be preceded by seismic assessments of the site.

Strategy 3: The agricultural or ecological value of the site should be conserved.

Ecological impact

Strategy 1: Any new development should be preceded by ecological risk assessments of the site.

Strategy 2: Damage to existing soil, water bodies and flora and fauna of the site and adjacent land due to construction process should be minimised.

Impact on nearby water bodies

Objective 1: To conserve the nearby water bodies

Strategy 1: Water contamination in nearby water bodies during the building operation should be minimised.

Built environment

Objective 1: To ensure that a good standard of day-lighting and natural ventilation is provided

Strategy 1: The daylight factor must be at least 2.3% in bedrooms, at least 1.5% in living rooms, at least 2% in dining rooms and at least 2.2% in kitchens.

Strategy 2: The lower floors of the buildings (where day-lighting and satisfaction of natural ventilation is not as good as the upper floors) could be designed for mixed-use purposes which are not entirely dependent on day-lighting and natural ventilation.

Strategy 3: The location of openings should promote both natural and cross ventilation.

Objective 2: To maximise acoustic privacy for all occupants and prevent disturbances from external noise sources on lower floors

Strategy 1: The walls of the apartments should be able to reduce external noise so that the background noise level does not exceed 31 dB.

Strategy 2: The floors on levels 1-10 should use appropriate noise attenuation treatments incorporated within the structure.

Construction practice

Objective 1: To ensure efficiency in overarching construction management

Strategy 1: The buildings should comply with national construction standards and building regulations.

Strategy 2: The environmental impact of constructing buildings should be considered.

Objective 2: To ensure safety for workers and pedestrians during building construction

Strategy 1: Practices that avoid building materials falling off during construction should be adopted.

Strategy 2: Practices that avoid construction accidents should be adapted.

Strategy 3: Construction workers should be educated on the importance of safety in building construction and be provided with the appropriate safety equipment

Objective 3: To ensure safety of the occupants

Strategy 1: Construction quality and structural safety should not be compromised under any circumstances.

Strategy 2: Ensure adequate structural strength.

Strategy 3: A monitoring unit to ensure safe building construction.

Strategy 4: Updating of building construction rules and regulations.

Objective 4: To ensure construction practice that facilitates ease of construction and minimal material wastage

Strategy 1: Coordination about the size/amount of building materials with building design to minimise waste.

Objective 5: To ensure safety of occupants under fire conditions

Strategy 1: The design of buildings and services should meet the fire safety standards in the BNBC (Bangladesh National Building Code).

Strategy 2: Easy accessibility of fire fighting vehicles to the building premises must be provided.

Strategy 3: Fire drills must be conducted by responsible fire wardens and management staff at regular intervals.

Strategy 4: Mandatory fire-fighting training for the staff and occupants of high-rise residential buildings must be provided.

Objective 6: To ensure the building does not collapse during natural disasters

Strategy 1: The structure of the building needs to be designed for maximum flexibility.

Building material

Objective 1: To ensure proper selection of building materials

Strategy 1: Durable building materials should be used.

Strategy 2: Building materials that are suitable for the site's climate should be used.

Strategy 3: Local building materials should be used.

Strategy 4: Non-hazardous building materials should be used.

Strategy 5: Materials that require minimum cleaning and maintenance should be used.

Resource management

Objective 1: To ensure operational efficiency of all resources (water, gas and electricity) services

Strategy 1: Electricity, gas and water usage in the building needs to be digitally metered.

Objective 2: To ensure conservation of water use

Strategy 1: The apartments should have water efficient plumbing fixtures, fittings and appliances.

Strategy 2: The buildings must harvest rainwater for purposes such as flushing toilets, washing cars and gardening.

Strategy 3: The buildings must use grey water for purposes such as flushing toilets, washing cars and gardening.

Strategy 4: The buildings must use and manage storm-water for landscaping.

Strategy 5: Water use during construction must be minimised.

Objective 3: To ensure efficient energy management during the construction stage of buildings

Strategy 1: Energy use during building construction stage must be minimised.

Objective 4: To ensure efficient energy management during the operational stage of buildings

Strategy 1: The apartments must have energy efficient lighting systems.

Objective 5: To ensure power smooth operation of elevators during power failure

Strategy 1: Standby power generators should be provided to support elevator use during power failures.

Objective 6: To reduce the total annual cooling electricity use

Strategy 1: If an apartment is large, it needs to be on a higher level of the building.

Strategy 2: If very low temperatures are preferred for set-point temperature ranges of air conditioners, the usage time should be short.

Waste management

Objective 1: To ensure efficient household waste management during the operational stage of building

Strategy 1: The building premise should have designated space with three bins for proper collection of waste in the building in cases where there is no door-to-door collection.

Strategy 2: The building should have garbage chutes for collecting organic household waste.

Objective 2: To ensure efficient management of construction waste on site

Strategy 1: Recyclable and recovered resources should be redirected to appropriate sites.

Objective 3: To ensure safety from hazardous waste on site

Strategy 1: Hazardous waste on site should be handled safely and stored separately.

Strategy 2: Use of hazardous materials like volatile organic compounds, timber preservatives, PVC, etc. should be avoided