ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS IN DHAKA CITY: IMPLICATIONS FOR SUSTAINABLE URBAN PLANNING

by

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It is hereby declared that this thesis entitled **'Energy Efficiency of Residential Buildings in Dhaka City: Implications for Sustainable Urban Planning'** or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Abstract

Energy is the burning issue for the twenty-first century Bangladesh. Due to frenzied urbanization and limited resources to generate power, the economic activities are being greatly hampered by power cuts; meanwhile the power sector is suffering from lack of capital, inadequate gas supply and high rate of system loss. Dhaka consumes almost 55% of total generated electricity according to the Dhaka Power Distribution Company Limited (DPDC). The domestic sector is the main consumer of commercial energy in Dhaka city. The latest records show that the domestic category alone consumes more than 40% of the total sale of DPDC. Therefore, energy efficiency improvements in residential buildings have large potential for energy conservation. Proper policy measures could enable the residential building sector to function more efficiently which would ultimately ensure sustainable urban environment.

The present thesis examined the electricity end-use pattern in residential apartment buildings of Dhaka City in the context of growing density and vastly reduced scope for natural lighting and ventilation. The study intended to evaluate the energy performance of buildings of this particular type against the urban textural quality that affects urban micro-climate. The assumption was that the energy efficiency of residential buildings is affected by provision of natural lighting, ventilation and thermal environment. The study findings revealed that different types of residential developments vary in urban textural quality and there is substantial variation in 'energy efficiency' of buildings in these locations.

The survey findings showed clear indications for the physical and environmental characteristics of immediate surroundings of a residential building having substantial impact on building 'energy efficiency'. Increased awareness and incentives to conserve energy by adopting efficient design measures and energy efficient technology can be vital to improved energy efficiency in buildings as higher affordability and ignorance can lead to misuse of energy. As the most appropriate solution at hand, the flourishing sector of multi-storied residential apartment buildings demand more in depth research regarding appropriate scale, form, building material, utility and mechanical systems etc. in order to make the whole system more efficient to reduce its adverse impact on the environment. This can be achieved through holistic planning approach and adoption of result oriented design measures by the city planner's and implementation of control and enabling policy measures from the policy makers' part.

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CHAPTER 1

INTRODUCTION

1.1 The Problem

Energy is a burning issue for the twenty-first century Bangladesh. With the ever growing demand for energy to cope with a developing economy on one hand and the impact of climate change on the natural environment on the other, ensuring adequate supply of energy and its efficient use has become the key factor for the country's sustainable development. Due to frenzied urbanization and limited resources to generate power, economic activities are being greatly hampered by power cuts; meanwhile the power sector is suffering from lack of capital, inadequate gas supply and high rate of system loss.

Due to spatially unbalanced urbanization country-wide, all the major economic activities are concentrated in the capital city of Dhaka .With only 43% electricity coverage country wide, Dhaka consumes almost 55% of total generated electricity according to the Dhaka Power Distribution Company Limited (DPDC). Therefore there is a tremendous pressure of population and consequential infrastructural and accommodation requirements for domestic, commercial, service sector and industrial activities in this city. As accommodating more and more people in a limited space has become the priority issue, extremely increased density is creating pressure on utility services which is evident in increased rate of load shedding and irregular electricity supply. On the other hand, land scarcity and high demand of housing units in the urban area has resulted in a development trend characterized by very closely spaced high-density building blocks without the provision of open space and greenery. These buildings are deprived of natural ventilation and lighting provisions and suffer from urban heat island (UHI) effect resulting in dependency on artificial lighting and air conditioning. A recent study (Roy, 2003) on residential areas of Dhaka showed that where building mass density and proportion of hard surfaces is higher, temperature is also higher. Therefore, if not properly addressed, energy for electric lighting and mechanical cooling/ventilation will continue to increase and urban micro climatic effects will hamper indoor and outdoor space comfort level.

The present thesis is based on the argument that, improved energy efficiency in urban buildings should be the focus of urban planning so that the urban development pattern is conducive to sustainable energy consumption. To incorporate energy efficiency issues in urban development planning, the planners need to evaluate energy end-use pattern in urban buildings along with the different socio-cultural, economic and physical environmental factors affecting it. The researcher intends to examine the existing energy end-use pattern in residential buildings located in different areas of varying development characteristics within the Dhaka City Corporation area with the assumption that the energy efficiency is affected by the micro-climatic condition and access to natural light, which are functions of surrounding urban texture and ambient environment of a building. This research argues that, it is important to understand the relationship of urban micro climatic nature resulting from urban form and texture with energy consumption in residential buildings to make future design decisions for residential developments and also improvement measures for existing ones to ensure sustainable energy consumption.

1.2 The Context

1.2.1 Energy , urbanization and sustainability issues world wide

Cities are the principal consumers of energy. Despite only representing 2% of the worlds land surface, they are responsible for 75% of the world's energy consumption (Boyd, 2008) With increasing urbanization in the world, cities are growing in number, population and complexity; and according to the United Nation's Intergovernmental Panel on Climate Change, in the coming years, two-thirds of the growth in global electricity usage will be seen in the developing world and mostly in its cities. However, dependency on fossil fuel for the supply of energy to these cities and the reality of ever growing demand has imposed two most pressing issues challenging the sustainable development of the modern world, energy crisis and climate change. Concerns are growing all over the world about the environmental and social impacts of the heavy reliance on fossil fuels which include air pollution, frequent natural disasters due to global warming, waste disposal problems, land degradation and the depletion of natural resources. Governments are setting carbon emission reduction targets as improved energy efficiency of urban activities and development is understood to be one of the key factors for sustainability of cities

With increasing urbanization and the consequent rise in energy demand for private and public consumption and for economic activities, there is an urgent need for energy efficient urban planning and construction (UNEP, 2001). It has been well established that urban energy efficiency is essentially dependant on the energy efficiency of its buildings as they account for at least 40% of the energy use in most countries in the world. No other individual sector has the same impact in terms of energy use and associated green house emissions (WBCSD, 2007). As significant users of energy and materials in a society, energy conservation in buildings plays an important role in urban environmental sustainability. As a response to this realization, city authorities in many countries have taken up policies, regulations and standards for energy use to enhance energy efficiency and promote energy conservation.

In the developing countries, like Bangladesh, the high rate of urbanization leads to higher densities than traditional settlements. Today the challenge before many cities like Dhaka is to support a large number of people while limiting their impact on the natural environment. Therefore, the task of architects, planners and other building professionals today is to design and promote low energy buildings in a cost effective and environmentally responsive way, although in high density cities, because of limitation of land and space and the reduced scope for natural lighting and ventilation, the task is complicated and hard to achieve. In case of Dhaka, the large population, land scarcity, lack of natural resources etc. makes the situation all the more complicated.

1.2.2 Energy situation in Bangladesh

Bangladesh is not well endowed with conventional sources of energy. The country's energy sources are neither adequate nor varied. Conventional commercial sources of energy in the country include fossil fuels, such as coal, oil, natural gas and hydropower. The power generation system is basically mono fuel based as about 90% power is produced from natural gas. Other option is the lone Hydro Electric Plant at Kaptai. The only coal based plant is at Barapukuria and several small furnace oil and diesel plants in the northern and southern region.

The total installed generation capacity of the country is about 5269 MW (as on June 2007). Electricity generation grew at about 7% p. a. during the last fifteen (15) years compared with average annual GDP growth rate of about 5.5%. Bangladesh's per capita electricity generation of 165 kWh per annum (ADB,2007) is still among the lowest in the world. Table 1.1 shows the electricity consumption per capita in South-Asian countries. About 43% of the population of Bangladesh has access to electricity, which is also low compared to many developing countries. This implies that the power sector has to increase significantly. Given the huge investment requirement for power development in the country, Bangladesh would be looking forward to various sources of finance. The Government has already opened the power sector for private investment and "The Private Sector Power Generation Policy" has been formulated in 1996 (source: www.powercell.gov.bd). Table 1.2 depicts the power sector in Bangladesh at a glance.

Table 1.1: Electricity consumption in South-Asian countries

Country	Annual consumption per capita, KWh (as of 2003)	Country	Annual consumption per capita, KWh (as of 2003)
Bangladesh	145	Srilanka	407
Bhutan	218	Avg. developed countries	1,157
India	594	Avg. world	2,490
Maldives	490	Avg. high income countries	10,331
Pakistan	493		

Source: UNDP 2006 op cit, pp. 354-356

Table 1.2: Power Sector at a glance (As on June 2007)

Generation	
Installed Capacity:	
(a) BPDB	3,872 MW
(b) IPP and Mixed Sector Total	1,397 MW
Total	5,269 MW
Maximum Demand Served, Total	3,785 MW
Net Energy Generation	23,267 M kWh
Transmission	
Transmission Line:	
230 kV	1,467 Ckt km
132kV	5,578 Ckt km
Total	7,044 Ckt km

(contd.)

Capacity of Grid S/S:	
230/132 kV	5,175 MVA
132/33 kV	7,219 MVA
Distribution	
Distribution Line (33 kV, 11 kV and 0.4 kV)	2,71,142 km
Total no. of Consumers	10.42 Million
Total no. of Agricultural Consumers	2 Lac 26 Thousand
Total no. of Village Electrified	50,360
Access to Electricity	43%
Per Capita Generation	165 kWh
System Loss (T and D)	19.30%

Source: www.powercell.gov.bd, 2009

The highest portion of generated electricity is consumed by the industrial sector where domestic services claim the second largest portion (Figure 1.1). However the average growth rate of electricity consumption is the highest in domestic sector (Figure 1.2) which is 9.2 while the same is 8.7 in the industrial sector(BBS 2005).

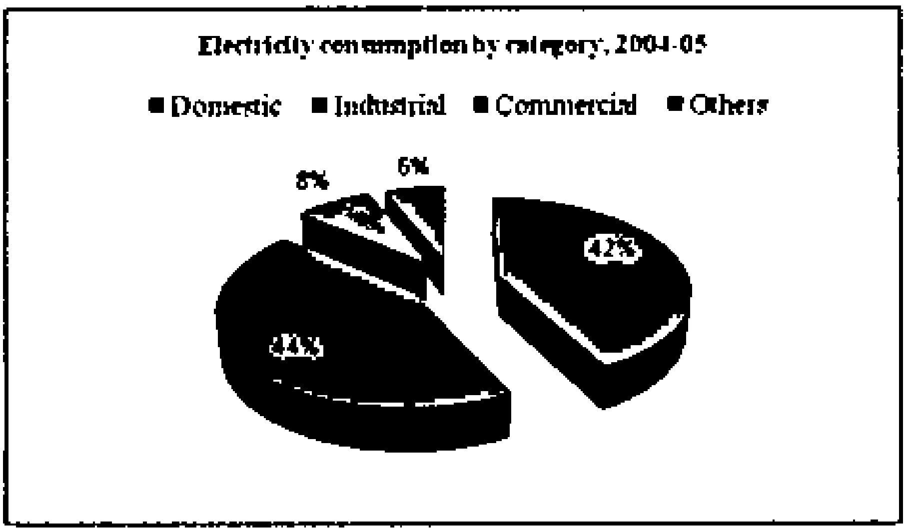

Figure 1.1: Electricity consumption by category, 2004-05,

Source: BBS 2005

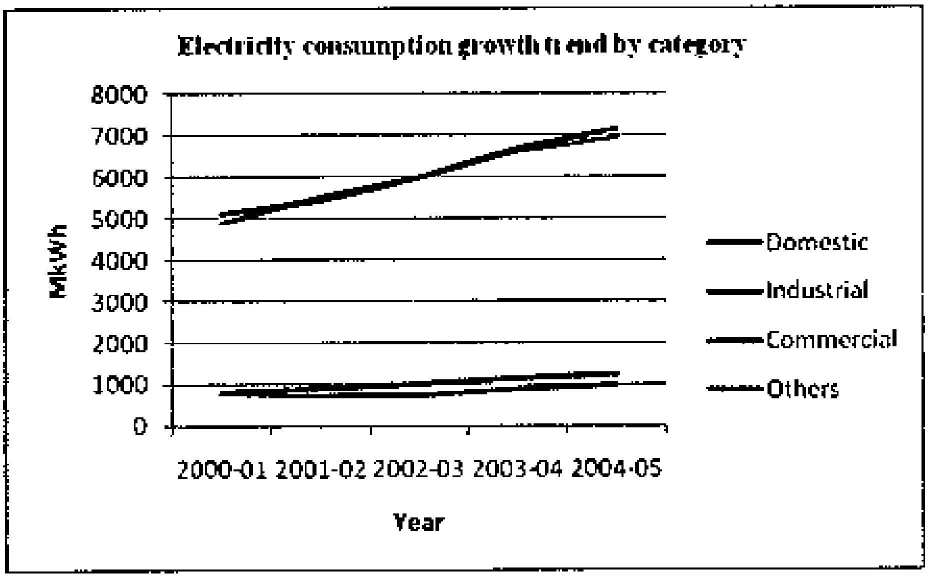

Figure 1.2: Electricity consumption growth trend by category

Source: BBS 2005

The Government of Bangladesh has prepared a draft Renewable Energy Policy and is seriously considering electricity generation from all possible sources of renewable energy such as wind, solar, biomass, biogas, mini-hydro, and solid waste.

1.2.3 Urban sector profile of Bangladesh

Bangladesh has an estimated current population of 140 million people, a quarter of which or 35 million people reside in the urban areas. By 2015, more than half of the country's population is projected to live in urban areas according to an Asian Development Bank (ADB) Country Report of 2005. Even though the level of urbanization is still low, the growth rate of urban population is very high. The report also says, the rate of growth of urban population is almost double that of the total population growth, at 2.5% per annum compared to 1.4% total population growth rate. The urban development trend is characterized by considerable regional and spatial variation across the administrative divisions, which creates a scenario of highly unbalanced development. Centered on the mega-city of Dhaka, where urbanization is estimated to be more than 50%; there are corridors of urbanization radiating from Dhaka towards the west, the northeast and the east following the highways, and to the southeast to some extent along the water routes. The remote districts have lower rate of urbanization than the national average.

Given the primarily agrarian and rural nature of the economy, the urban sector traditionally did not receive adequate attention in terms of policies and investments. The result is massive urbanization and urban growth which is unplanned, unregulated and uncontrolled. This resulted in severe pressure on utility services such as electricity, water supply and sanitation systems. Shortage of housing is forcing people to squat on government and private lands often in the urban fringes. Infill developments are making urban open spaces disappear and deterioration of the urban environment.

The National Program Document for the Urban Sector of 1994 claims that one of the *de facto* urban policies in Bangladesh is to promote "economic decentralization" and "balanced growth", by which are meant the de concentration of population and economic activity away from Dhaka and the other large cities. Despite this realization, the actual scenario is that the secondary towns have been growing without any physical and development plans and as there is no planned attempt to divert people from the large cities to the secondary towns. every year thousands of people migrate to Dhaka putting tremendous pressure on housing and related facilities.

1.2.4 Housing situation in Dhaka City

Dhaka city adds almost half a million people to its population each year given the growth rate of 4.34 percent, according to a World Bank report (2007). To accommodate the new people the city would need at least 10 million new units by the year 2015 According to the latest data available, 26% of Dhaka city's land area is occupied by residential land use (*Survey of Bangladesh, 1995)).*

Private sector housing is one of the fastest growing sectors in the economy of Bangladesh and it concentrates its activities mostly in Dhaka. The conversion of Dhaka from an ordinary town to a metropolis is manifest in the transformation of the nuclear houses into multi-level apartments. Inadequate supply of developed land and high construction costs are the major constraints in most new formal sector residential construction in Dhaka. The issue of efficient utilization of residential land for urban housing development has always been central to urban planning. This is particularly so considering the fact that the utilization of residential land vis a vis appropriate housing type has exposed the plight of the urban majority of middle class dwellers in

Dhaka (Kamruzzaman, 2007). Average total floor space for an urban household was only around $30m^2$ and per capita floor space averaged $5.1m^2$ in 1991, while in the densely populated slums, a floor area per capita as small as 1.2 to $1.5m^2$ was a common feature (Islam, 1996).

According to the proposed National Housing Policy 2004, the current nationwide housing requirement stands at 2 million, increasing at a rate of 372,000 dwelling units/year. The urban housing need was 658,000 units/year between 1993 and 2000 including requirements for new dwellings, replacements and backlog; 60% of it for the poor. Dhaka, a city of 12.5 million people increasing at 5% rate, had an annual requirement of 218,000 dwelling units up to the end of the century which included 80,000 new dwellings; 102,000 replacement units and 35,000 backlog units (BCL et.al., 1996). Nearly two thirds of these were required for the poor (Rahman, 2005).

The Government of Bangladesh cannot cater to the housing needs of its citizens on its own due to its paltry fiscal capacity. Thus, the formal private developers' are popular to the high income and middle income group as housing provider and their popularity is growing rapidly. Developers started housing projects in Dhaka in the late seventies. During the 1970s there were fewer than 5 companies engaged in the housing sector. In 1988, there were 42 such developers working in Dhaka and in 2004 the figure has increased to about 250. During the last 20 years the private developers delivered 700,000 to 800,000 unit apartments in Dhaka. According to the database of Real Estate and Housing Association of Bangladesh (REHAB) (2004), developers are supplying an average of 6,000 apartment units each year.

1.3 Research Objectives

1.3.1 Main goal of the study

The main goal of the study is to contribute to a better understanding of the physical characteristics of urban development form that is conducive to efficient energy consumption, focusing on the residential part of the urban development. This research intends to describe the existing situation regarding the energy performance at the operation stage of the contemporary form of residential buildings, that is, the apartment buildings in Dhaka city. It is also intended to examine the variation of energy consumption in buildings in relation to the varying urban textural and microclimatic characteristics of the locations which is assumed to have resulted from the form of urban development that took place there, so that the findings can be useful to make future urban planning decisions regarding sustainable energy consumption

1.3.2 Specific objectives

The specific objectives of this study are as follows;

I. To determine the existing energy efficiency of residential buildings of Dhaka in terms of KWh/ m^2/yr.

II. To evaluate the relationship between energy efficiency of a residential building and surrounding urban texture and ambient environment.

III. To evaluate the planning implications of the findings of the above objectives for sustainable energy use in Dhaka city.

1.3.3 Definitions and explanations of relevant terminologies

Before going to the actual thesis, some relevant terms needs to be determined in order to understand the problems and prospects regarding energy efficiency in buildings and consequentially in urban development planning.

1.3.3.1 Energy efficiency

The quantitative definition of 'energy efficiency' regarding buildings is the amount of energy consumed by a building per unit area for a specific time period for its construction, operation and maintenance, which is usually expressed in KWh/m^2/year.

The qualitative aspect of energy efficiency in buildings involves reduced energy consumption for acceptable levels of comfort, air quality and other occupancy requirements, including the energy used in manufacturing building materials and in construction.

For this research, the actual consumption of energy in the form of electricity in a building for occupancy requirements is termed as 'energy efficiency' of that building denoted by KWh/m^2/year.

1.3.3.2 Urban texture

The term 'urban texture' generally relates to urban geometry, urban form and also the surface quality of urban areas. All of these aspects of urban area have impact on the urban micro climate therefore have strong relationship with energy consumption in urban buildings. The idea of applying texture analysis to urban areas was originated from the consideration that an urban area can be defined on the bases of urban elements. In accordance with this consideration a urban texture definition can be given as the geometrical structure formed by the spatial distribution of urban elements as buildings, roads and green areas.

Many researchers have done urban investigations through urban texture analysis, such as, Ratti (2004, 2006) used 'raster models' or DEMs (Digital Elevation Model) of cities for surface –volume analysis regarding energy consumption in buildings, Myint (2003,2005) used remotely sensed images for urban mapping, Lark (1996) used aerial photographs for classification of land cover, etc. The present research examined the urban texture in a similar way by looking into the surface quality and physical form of the surroundings of a building to ultimately relate with it's energy consumption profile.

In this research, satellite images from 'Google Earth' has been used for mapping two components of urban texture which are considered for examining their effect on energy consumption of residential apartment buildings, these are: open space and built up area ratio and soft surface and hard surface ratio.

1.3.3.3 Sustainable urban planning

The process of urban planning that is aimed and expected to achieve 'sustainable development' can generally be termed as 'sustainable urban planning'. The concept of 'sustainable development' is used to refer to alternatives to traditional patterns of physical, social and economic development that can avoid problems such as exhaustion of natural resources, ecosystem destruction, pollution, overpopulation, growing inequality and degradation of human living conditions (Wheeler, 1998).

The most widely used definition is given by the Brundtland Commision[1]: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Another definition given by the World Conservation Union in 1991 is; "improving the quality of human life while living within the carrying capacity of supporting ecosystems". A more relevant definition, considered for the present study, is given by Stephen Wheeler, 1998, 'development that improves the long-term social and ecological health of cities and towns might be called sustainable urban development.'

1.4 Research Rationale

In the context of high demand for energy in the residential sector challenged by energy scarcity and the consequential deterioration of quality of living environment in Dhaka, it is essential to consider the building energy consumption pattern seriously as a component of sustainable urban planning process. Therefore the research rational of the present study places itself in the realm of constructing a base line scenario of energy consumption in residential buildings of Dhaka city. The findings of this study is hoped to contribute in future decision making for spatial and policy planning to achieve energy efficiency goals.

1.5 Scope and Limitations of the Study

The present research concerns itself with the consumption of final energy in the form of electricity in apartment type residential buildings located in different residential areas within the Dhaka City Corporation area. The consumption pattern is related with selected parameters of the urban textural quality of immediate surroundings and micro climate. Consumption of primary energy, such as natural gas or fuel oil in the household level is not considered in this study.

The study targeted only the apartment type residential buildings which are the most popular and a flourishing form of dwelling pattern in recent times. These buildings are constructed by individual land owners, private developer firms and also by public sector as housing facilities for specific target groups. The individual apartment units

[1] An early and influential report on sustainability is the World Commission on Environment and Development, *Our Common Future* (New York: Oxford University Press 1987), commonly referred to as the Brundtland Report.

are rented, bought, allotted or occupied for a specific period by households ranging from higher middle to higher income group.

The study was done with the intension to examine the energy consumption in residential apartment buildings in varying types of development existing in Dhaka city and the impact of building density, surface quality and ambient temperature of the immediate surroundings. The assumption was such that, the widely spaced walk up residential apartment buildings having better provision of green spaces around would consume less energy as a result of cooler ambient environment and greater access to natural light. On the other hand the densely constructed multistoried apartment buildings equipped with elevators would be more energy intensive.

As electricity consumption largely depends on the affordability and personal perception of comfort among many other factors, the study does not claim to justify or explain the energy performance of the case study buildings based on the results of the selected parameters. It only depicts the existing situation and tries to relate the consumption profile with certain physical characteristics in the context of Dhaka.

The main limitation of the study is the small sample size taken by this research due to time and resource constraints. This is a drawback for any correlation analysis to get significant correlation between two variables. The socio-cultural reality of modern Dhaka has played a crucial role. Getting full record of electricity bills from households are often impossible because either they do not preserve them or they do not want to share the information with a surveyor. Finding buildings occupied by households who will cooperate was a major challenge for this research.

The study used household energy consumption data supplied by the user without checking their reliability. This is a concern because metering and billing system of electricity consumption has often been infiltrated by tampering of equipments and illegal interventions. Also, households often hesitate to reveal their true consumption.

Lastly, the limitation of quantifying the urban textural quality by estimating green coverage, exposed hard surface, built-up and open space from analyzing a two dimensional satellite image is that, it is impossible to do it with actual precision. The study had to settle with back-dated images available from 'Google Earth'. Also the estimations of the proportion of green coverage, exposed hard surface, built-up and open space within the surveyed areas are subjected to change with different boundary limit.

1.6 Literature Review

A lot of work has been done by many researchers both in developed and developing countries on issues related to energy efficiency since the early 80's when the first shock of energy crisis was felt by the human race. Researchers have examined the energy consumption pattern in cities and the effect of urban development form on it. The concept of Sustainable Urban development has always been linked with efficient use of the limited resource of fossil fuel. The present research reviewed the more recent works on energy consumption in urban buildings, impacts of urban development form and urban planning on it and the prospects and barriers to energy efficiency in buildings.

1.6.1 Concepts of sustainable urban planning

In 2007, 50 per cent of the total global population lived in cities. This figure alone demonstrates the important role that urban planning and development has in achieving a more sustainable development, both in the developed and the developing countries. Planning for a sustainable urban development must be oriented towards long-term goals by utilizing knowledge about the environmental consequences of different solutions, but should not be based solely on means-ends rationality. Rather than aiming at consensus including all stakeholder groups, planning for sustainability should facilitate alliance-building among those population groups who can support the basic equity and environmental values of a sustainable development (NAESS, 2000).

Until the early 1990s very little of the sustainable development literature focused on cities or patterns of urban development. Instead, writers addressed topics such as the global environmental crisis, ecological economics, critiques of prevailing models of international development and the need for a transformation of values and mindsets. However, in recent years architects and planners have begun looking more specifically at what sustainability means for patterns of metropolitan development. Emphasize has been given on urban design and physical planning along with on environmental planning which concerns with the quality of air, water and natural eco-systems. It has also been stressed that social problems and inequities within the urban community should be addressed as environmental and social issues are inextricably linked (NAESS 2000).

1.6.2 Energy issues in urban planning

Well planned cities portray efficient use of space and energy. Energy is one of the more important factors that define the quality of urban life. Rapid urbanisation process has dramatic affects on energy consumption. A recent analysis, showed that a 1 percent increase in the per capita GNP leads to an almost equal (1.03%) increase in energy consumption. On the other hand, an increase of the urban population by 1 %, increases the energy consumption by 2.2 %, i.e., the rate of change in energy use is twice the rate of change in urbanization (Santamouris, 2002).

The impact of urban development form on urban micro climate, transportation network, industrial, commercial and residential land use pattern etc has consequences on urban energy requirements. Therefore, policy makers try to develop an integrated energy planning should include sustainable energy supply systems based on renewable sources, use of demand side management techniques to regulate the consumption of big users and integration of passive solar systems in the envelop of existing and new buildings and use of high performance supply and management equipments.

1.6.3 Urban development form and energy consumption

The process of urban development in a naturally growing city or in a city with loose development control generally results in several types of physical developments, which are collectively called urban development forms (UDF). Anderson et al. (1996) defines UDF as spatial patterns of human activities at a certain point in time. This implies that urban development forms are either planned or unplanned entities.

In the cities of developing countries, the embryo of the city's center is grown organically from an originally uncontrolled residential area which later invites commercial activities to form mixed land use. As the city grows, the authority regulates this area to become a controlled residential cum commercial area. Patterson

(1979) notes that planners are increasingly dealing with the problems of accommodating complex mixes of land uses at close quarters, especially in central cores and at satellite nodes. One of the benefits of mixed land use is its ability to reduce transport energy by creating biking or walking communities due to the proximity of origins and destinations where there are mixed land uses.

Location, physical feature and ambient environment of a city are the three factors that affect energy use at the city level. In residential areas, physical feature of the urban development form may include residential density, floor area, floor area to land ratio, and also population density. More recent literature is inconclusive as to the relationship between building energy use and urban form. Some authors conclude that higher building densities reduce energy demand (e.g Holden *et al*, 2004; Mindali *et al*, 2004) whilst others believe that increasing density can increase energy demand due to restrictions on natural ventilation and light, and opportunity for solar gain (e.g. Hui, 2000, and Larivière *et al*, 1999). However, it is also possible that a high density urban area, obtained by a mixture of high and low buildings, could have better ventilation conditions than an area with lower density but with buildings of the same height (Hui, 2000).

In a review of the issues related to housing, Steemers (2003) concluded that energy arguments for and against densification of 6 cities is finely balanced, and depended upon infrastructure issues (i.e. opportunities for buildings to share water and energy networks; CHP and district heating). However, as solar obstruction angles (a product of building height and separation) increase above about 30°, densification becomes unattractive from an energy efficiency perspective, because buildings facades and roof tops are more likely to be over-shadowed as well as obstructed by adjacent buildings and remain deprived of natural light, solar gain and natural ventilation Therefore densification can lead to higher energy consumption for HVAC and lighting requirements.

1.6.4 Urban texture, urban climatology and energy consumption

Urban texture features many forms of built and natural environment, and simultaneously the presence of built-environment is exhibited by numerous forms. Therefore, it is too complicated to generalize and model an urban texture. However.

some studies attempt to model urban area with respect to urban vegetation and microclimates as shown by various authors and researchers (Sashua-Bar et al, 2006; Simpson, 2002; Sashua-Bar and Hoffman, 2000 and Takakura et al. 2000).

Sashua-Bar et al. (2006) attempted to simplify urban built-environment into three generic models those representing the most common types of residential urban streets, those are (a) the street form, a conventional type with spacing between the houses, (b) the canyon form, a limiting case of street form, and (c) the courtyard house form. From these simplifications, Sashua-Bar et al. (2006) tried to quantify the integrated thermal effect of built forms and of vegetation on the urban canopy layer climate in design built-up alternatives. It is found that the variation in thermal effects of the built form of vegetation and of colonnade can be explained by linear relationship respectively to high degree of accuracy The explanatory variables for the three cases are: (a) the envelope ratio for the built form effect, for street houses and for closed courtyards with and without colonnade; (b) the envelope ratio and the tree coverage level for the tree cooling effect; and (c) the reduction in envelope ratio due to colonnade area for the cooling effect of colonnade unit. The study also demonstrated that the smaller the envelope ratio, the cooler the built-up unit, and the larger the envelope ratio the tree effect is stronger.

The argument, that urban texture and vegetation has considerable thermal impacts in urban environment, is supported by Dimoudi and Nikolopoulou (2003). They argue that the physical impact of vegetation in the urban environment affects the thermal environment, air quality and noise. To support this hypothesis, microclimatic effects of vegetation with respect to reduction of air temperature was investigated; this was undertaken in order to mitigate the heat island effect, where most city centers experience significantly higher temperatures than the surrounding countryside. Size of green area, density of the urban texture, orientation, type of vegetation, wind speeds and distance from green area, have been considered in the study. The major finding of the study is that urban vegetation can greatly improve urban microclimate through its thermal effects, as well as mitigate heat island effect by reducing summer air temperature

In order to understand the relation of geometry, texture, vegetation and thermal comfort around buildings in urban setting, Masmoudi and Mazouz (2004) undertook a study with four variables involved, namely orientation of buildings, geometry, size and vegetation. From the study it was found that geometrical form of the building has important impact on the reduction of surface temperature. In the similar manner, the reduction of height of the building led to the fall of surface temperature, while variation of size of building had insignificant impact. Urban texture and vegetation, in the same way, had a great impact on the ambient environment of cities, and in particular, surface temperature of the buildings in cities.

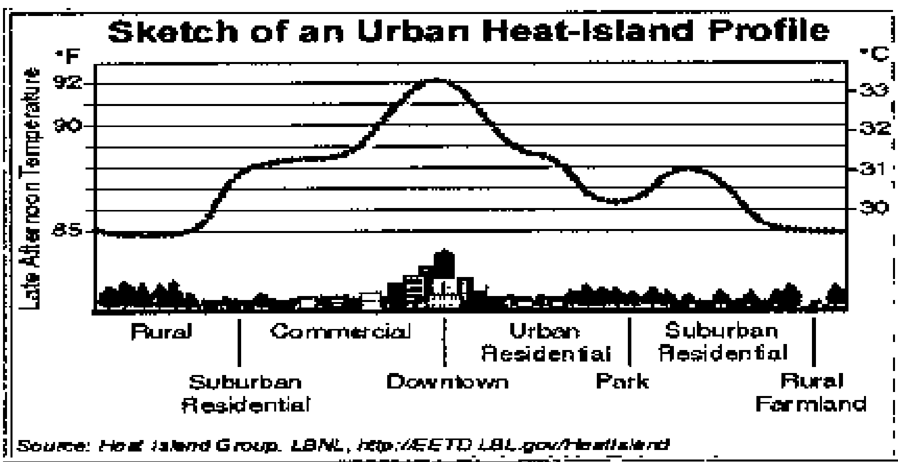

Figure 1.3: Sketch of an Urban Heat-Island Profile

The unique micro climate of cities is the product of their complex built environment, their lack of cooling vegetative surfaces, and their increased anthropogenic activity. These combine to create thermal contrast between urban and rural areas. The phenomenon is called urban heat island (UHI) effect (Figure 1.3). The primary root of heat island in cities is due to the absorption of solar radiation by mass building structures, roads, and other hard surfaces during daytime. The absorbed heat is subsequently re-radiated to the surroundings and increases ambient temperatures at night. In hot and humid weather it takes the whole night to cool off. By the time it is cool in the very early morning it begins to heat up again. So the nights and days are hardly comfortable.

The UHI phenomenon was first noticed by meteorologists more than a century ago (Howard, 1833). Since then, the UHI effect has been well explored worldwide (Oke, 1978; Landsberg, 1981; Santamouris, 2002; Akbari, Rosenfeld, and Taha, 1990; Tso, 1996). Some of the most important factors which may influence the UHI effect include canyon geometry, thermal properties of materials, anthropogenic heat, the urban greenhouse effect, and evaporation surfaces (Santamouris, 2002). According to Landsberg (1981), UHI, as the most obvious climatic manifestation of urbanization, can be observed in every town and city.

In rural areas, the surface is dominated by vegetation. from which water evaporates. In contrast, much of the surface in an urban environment has undergone waterproofing through the use of impervious materials, reducing the latent heat flux (Grimmond and Oke. 1999, 2002). On a neighborhood scale, the presence of a vegetated area or water body within a city can have a significant cooling effect on local temperatures (Graves et al., 2001; Spronken-Smithand Oke. 1999)

Within a city, temperature patterns are dominated by an inverse relationship between temperature and distance from the city centre, but are also strongly related to land use, which is often a surrogate for urban morphology and geometry as well as to surface characteristics such as the availability of water (Eliasson and Svensson,2003; Henry and Dicks,1987; Landsberg. 1981; Wilby(2003). Microclimate modification through the use of vegetation can also be integrated into the building envelope in the form of green roofs or bio-shaders (Niachou et al. 2001). This form of passive cooling not only brings benefits to the internal occupants of the building but also provides significant external cooling; potentially offsetting future temperature increases (Gill et al.. 2007). The use of water feature in a city offers an alternative to vegetation as a method of alleviating high urban temperatures by increasing the latent heat flux from the surface, as exemplified in Arabic and Indian architecture. The design of cities in Spain, e.g. Cordova, Granada etc. was done by integration of water and vegetation. making them the finest cities designed till today.

1.6.5 Techniques to improve urban micro-climate

As discussed previously. different researchers have worked on urban micro climatic effect and on thermal comfort in buildings and suggested ways to improve it by applying mitigating technologies. They can be summarized as below:

I. the use of more appropriate materials,

II. increased use of green areas,

III. use of cool sinks for heat dissipation,

IV. appropriate layout of urban canopies. etc..

Simple materials used in cities are characterized by various 'albedo values'[2] that determine the albedo of a city. Increase of the albedo has a direct impact on the energy balance of a building. Large scale changes on urban albedo may have important indirect effects on the city scale. Studies have been performed to evaluate direct effects from albedo change. The increase of the roof albedo of a house in Sacramento from 0.2 to 0.78 has reduced cooling by 78 %. Reflective roof coatings contribute to air conditioner electrical savings in the buildings up to 19 %, ranging from a low of 2 % to a high of 43 %. Utility peak coincident peak savings averaged 22 % with similar range of values.

Trees and green spaces contribute significantly to cool our cities and save energy. Trees can provide solar protection to individual houses during the summer period while evapotranspiration from trees can reduce urban temperatures. Trees also help mitigate the greenhouse effect, filter pollutants, mask noise, prevent erosion and have calm effect on the city dwellers. The American Forestry Association estimated that the value of an urban tree is close to $ 57000 for a 50 years old mature specimen. The estimate includes a mean annual value of $ 73 for air conditioning, $ 75 for soil benefits and erosion control, $ 50 for air pollution control and $ 75 for wildlife habitats. Trees and green spaces created oasis of 1-5°C during night in Athens. in San Fransisco's heavily vegetated Golden Gate Park average about 8°C cooler than nearby areas that are less vegetated. In Tokyo, vegetated zones in summer are 1.6°C cooler than non vegetated spots, while in Montreal, urban parks can be 2.5°C cooler than surrounding built areas. The park in Mexico City was 2-3°C cooler with respect to its boundaries. Similarly in Dhaka, the environment in the Dhaka University campus area remains much cooler than the surrounding areas with lesser vegetation, which is clearly felt by anyone passing through the region. Therefore the buildings have to be proportionately complemented by trees and greenery to tackle heat build-up and consequent increase in energy consumption.

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[2] Albedo or solar reflectance is the ratio of reflected solar radiation to the total amount that falls on that surface known as incident solar radiation. Albedo values range from 0 for perfect absorbers (dark paving) to 1, for perfect reflectors (light paving). An Albedo value of 0.8 means that 80% of all the energy striking a reflecting surface is reflected back into the atmosphere and only 20% of the energy is absorbed by the surface. Therefore, paving with high Albedo values assists in reducing heat islands.

1.6.6 Energy use in urban buildings

Urban energy efficiency is essentially dependant on the energy efficiency of its buildings. Buildings account for at least 40% of the energy use in most countries in the world. No other individual sector has the same impact in terms of energy use and associated green house emissions (WBCSD, 2007). As significant users of energy and materials in a society, energy conservation in buildings thus plays an important role in sustainable urban development. Building energy use is driven by demographics, economic development, lifestyles, changes in energy sources and technology.

Besides the operational energy requirements of buildings, there are two related energy issues; one is transport energy requirements as a result of the building and urban design parterns; the second one is the embodied energy or energy content of the building materials, equipment or systems being used. Research findings in some countries indicated that the operating energy often represents the largest component of life-cycle energy use (Hui, 2000).

1.6.6.1 Factors affecting energy consumption in urban residential buildings

Building energy performance is currently understood as dependent upon the following:

(1) Urban geometry,

(2) Building design,

(3) Systems efficiency and

(4) Occupant behavior.

It should be noted that these four points are under the control of different actors in the building sector: urban planners and designers in issue no. (1), architects in issue no. (2), system engineers in issue no. (3) and occupants in issue no. (4) (Ratti, Baker and Steemer, 2004). According to Baker and Steemers (2000) building design accounts for a 2.5 times variation in energy consumption, systems efficiency for a 2 times variation and occupant behavior for a 2 times variation (Figure 1.4). The cumulative effect of these factors can lead to a total variance of 10-fold. In practice, variance in energy consumption of buildings with similar functions can be as high as 20-fold which is presumed to be the resulting affect of 'urban geometry'.

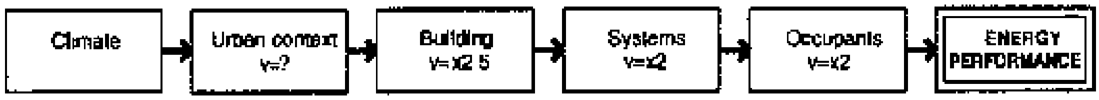

Figure 1.4: Factors that affect energy consumption in buildings; according to Baker and Steemers, 2000

Residential energy end-use occurs due to; HVAC requirements, cooking, lighting and refrigeration and other uses for different electrical equipments. There is a lack of data on the consumption pattern in the households of Bangladesh specifically Dhaka. But estimates for UK and Hong Kong households shows that (Table 1.3 and Figure 1.5) space heating and lighting requirements claim a major share ranging from 40% to 70% of total consumption.

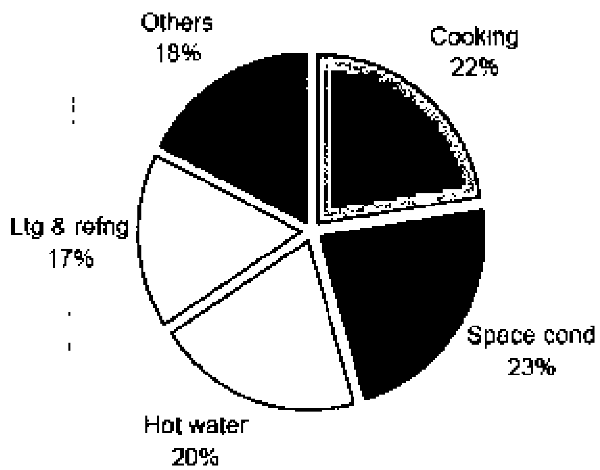

Figure 1.5: Components of residential energy end use in Hong Kong, 1995

Table 1.3: Energy Use Break Down (%) For UK Domestic and Commercial Buildings

	Housing	Office – air conditioned	Office -Naturally ventilated
Space heating	60	22	41
Water heating	23		
Lights and appliances	10	34	47
Fans/ pumps		30	12
Refrigeration		14	
Cooking	7		

Therefore, urban geometry which relates to the availability of sunlight and daylight on building facades and the urban micro climate has a key role to play in determining residential energy use.

A list of factors that influence the demand for energy in buildings has been summarized by M. Gordon (2005):

I. Type of activity (e.g. housing, commercial, industrial) and the occupant behavior;
II. Design factors related to urban geometry – e.g. obstruction angle (a product of height and plan depth/spacing to adjacent buildings), opportunity for passive solar gain;
III. Design factors related to buildings morphology – e.g. extent of glazing, orientation;
IV. Thermal properties of construction materials – relative amounts and U-values of materials used, embodied energy of material;
V. Efficiency of internal systems – e.g. heating and lighting systems, air conditioning use in offices (itself affected by external environmental quality);
VI. Opportunity for energy efficient sharing of infrastructure (e.g. water or energy networks);
VII. Internal and external temperatures;
VIII. Fuel price –affects consumption and fuel switching.

This is not an exhaustive or prioritized list, but does serve to illustrate that the range of variables that determine energy use in urban buildings is extensive.

1.6.7 Energy efficient building design

A challenging task for architects and other building professionals today is to design and promote low energy buildings in a cost effective and environmentally responsive way. Passive and low energy architecture has been proposed and investigated in different locations of the world (Yuichiro, Cook and Simos, 1991; Givoni, 1994); design guides and handbooks were produced for promoting energy efficient buildings (CIBSE, 1998; FSEC, 1984; State Projects, 1993; Watson, 1993).

Energy efficiency in buildings can be achieved through a multi-pronged approach involving adoption of bio-climatic architectural principles responsive to the climate of the particular location; use of materials with low embodied energy; reduction of transportation energy; incorporation of efficient structural design; implementation of energy efficient building systems and effective utilization of renewable energy sources to power the building (TERI 2001).

Architects can achieve energy efficiency in the buildings they design by studying the macro and micro climate of the site, applying bio climatic architectural principles to combat the adverse conditions, and taking advantage of the desirable conditions. A few common design elements within a site that directly or indirectly affect thermal comfort conditions and thereby the energy consumption in building are;

I. Landscaping
II. Ratio of built form to open spaces
III. Location of water bodies
IV. Orientation
V. Plan form and
VI. Building envelope and fenestration.

However, at present, little information is available for studying low energy building design in densely populated areas. In high density cities, because of the limitation of land and space, the energy efficiency task is more complicated. Designing low energy buildings in high density areas requires special care to the planning of urban structure, coordination of energy systems, integration of architectural elements, and utilization of spaces.

1.6.8 Barriers to improve energy efficiency in buildings

In today's world, knowledge and technical tools exist to design, construct and operate buildings more energy efficiently than business as usual and at the same time improve levels of comfort. However, the potential efficiency is not being realized due to certain behavioral, organizational and financial barriers. It is now well understood that the building sector is not able to pursue energy efficiency in buildings without the support of appropriate government policies (Koeppel et al, 2007). Barriers to energy efficiency improvements in buildings identified by Sustainable Building & Construction Initiative of UNEP (2007) are as follows;

a) **Economic/Financial Barriers**

Purchasing more efficient equipment usually involves higher first costs which many consumers do not want to spend and which low-income consumers cannot afford because they have limited capital (Carbon Trust, 2005).

b) **Hidden Costs and Benefits**

In addition to the higher up-front costs, there are hidden costs and benefits for the end-user not captured directly in financial flows, such as transaction costs associated with securing the energy efficient solution and risks associated with the replacement technology (Westling, 2003; Vine, 2005). Transaction costs are often high due to the fragmented structure of the buildings sector with many small owners and agents. New technologies might not be compatible with existing sockets for example (Carbon Trust, 2005). On the other hand, indirect benefits of improved energy efficiency, such as reduced air pollution and thereby improved health are often neglected as well.

c) **Market Failures**

Market failures prevent the consistent translation of specific energy-efficient investments into energy saving benefits (Carbon Trust 2005). Misplaced incentives are a major barrier in the buildings sector as building tenants pay the energy bill and are therefore possibly interested in reducing it, but have no control over the system, whereas building owners are not interested in energy efficiency improvements. Similarly, utilities have no direct interest in measures reducing their clients' energy use.

d) **Behavioral and organizational constraints**

Behavioral characteristics of individuals and organizational characteristics of companies hinder energy efficiency technologies and practices. Small but easy opportunities for energy conservation are often ignored and changing behavior or lifestyle is very difficult. (Shove, 2003; Chappells and Shove, 2005). A lack of awareness and information on the opportunities and low costs of energy savings are a related problem, even more in developing than in developed countries.

e) Political and Structural Barriers

Political and structural barriers mainly occur in developing countries and include problems such as lack of government interest in energy efficiency. insufficient enforcement of policies due to inadequate enforcement structures and institutions, lack of qualified personnel, and corruption (Deringer *et al* 2004).

f) Information Barriers

Lack of information about the possibilities, techniques and potentials of energy efficiency solutions is a major barrier in developing countries and therefore mentioned as a separate barrier category here (Evander *et al.*, 2004, Deringer *et al.*, 2004).

g) Special Barriers in Developing Countries

The special barriers in developing countries like Bangladesh include lack of awareness on the importance and the potential of energy efficiency improvements, lack of financing, lack of qualified personnel and insufficient energy service levels (Urge-Vorsatz *et al*, 2007).

Sometimes if low-quality versions of the efficient technology enter the market first, the early movers may experience disappointment in the technology and may not try the higher quality versions again, such as in the case of some low-cost CFLs that fail prematurely. Energy efficient equipment, together with other equipment, is often not sufficiently certified and checked for quality in these countries

Subsidized, not cost-reflective energy prices are one of the most important barriers in many developing countries. High cost-reflective energy prices have been cited as one of the most important success factors for energy efficiency programs in developing countries, for instance in Brazil, Malaysia and other countries. However, in the poorest countries subsidies enable minimal energy service levels to certain population groups, so taking them away may be socially difficult.

In countries or regions with lack of access to reliable energy supply such as Africa, south Asian countries like Bangladesh, the priority of governments is to improve access to energy for inhabitants rather than to improve energy efficiency. Therefore, renewable energy projects and rural electrification often play a more important role for governments than energy efficiency (Mueller, pers. comm. 2007).

1.6.9 Policy measures to improve energy efficiency for buildings

Building energy efficiency standards and regulations are policy measures widely used to control energy consumption in buildings (Janda and Busch 1994). It can help overcome some of the significant market barriers and ensure that cost-effective energy efficiency opportunities are incorporated into new building. This is particularly important for in developing countries where the number of new buildings is growing rapidly and the energy prices and market often do not encourage the use of efficient technologies.

Policy instruments to promote energy efficiency in buildings can be of various type . They are identified and compared against their effectiveness by UNEP SBCI(2007);

a) Regulatory and control instruments: appliance standards, building codes, procurement regulations for the public sector, Energy efficiency obligations(EEOs) and quotas, mandatory certification and labeling, audit programs and utility demand-side management programs.
b) Economic and market-based instruments Energy performance contracting, technology procurement, energy efficiency certificate schemes and Kyoto flexibility mechanisms i.e. CDM (Clean Development Management) projects.
c) Fiscal instruments and incentives: energy or carbon taxes, tax exemption and reduction, public benefits charges, capital subsidies, grants, subsidized loans and rebates.
d) Support, information and voluntary action: voluntary certification and labeling programs, voluntary and negotiated agreements, public leadership programs, awareness raising, education and information campaigns and detailed billing and disclosure programs.

Several developing countries have already enacted legislation on energy efficiency in buildings, for example Thailand, India, China, South Africa, Egypt, Bahrain, Tunisia, Morocco, Mexico, Brazil, Argentina, Chile, Colombia, Ghana and Peru. A number of other countries such as Kenya, Uganda and the United Arab Emirates are currently introducing such mechanisms, often supported by international organizations. The most commonly applied measures are voluntary and mandatory labeling, appliance standards, building codes, public leadership programs, DSM (Demand side management) programs, subsidies, grants and rebates, awareness raising campaigns and mandatory audits (UNEP SBCI,2007).

1.6.10 Existing policy and regulations in Bangladesh

Although National Energy Policy and Environmental Policy both recognizes the importance of energy conservation, at present efficiency in energy use is quite low (NEP, 2004). Till now Bangladesh has no Energy Standards for buildings. Recently, Ministry of Power, Energy and Mineral Resources, Government of Bangladesh has drafted the 'Renewable Energy Policy 2008' and 'Energy Conservation Act 2008' which includes a chapter on 'Building Related Energy Code' to ensure rational and efficient energy use in buildings.

The objectives of National Energy Policy (NEP) are;

I. To provide energy for sustainable economic growth so that the economic development activities of different sectors are not constrained due to shortage of energy.

II. To meet the energy needs of different zones of the country and socio-economic groups.

III To ensure optimum development of all the indigenous energy sources.

IV. To ensure sustainable operation of the energy utilities.

V. To ensure rational use of total energy sources.

VI To ensure environmentally sound sustainable energy development programs causing minimum damage to environment

VII. To encourage public and private sector participation in the development and management of the energy sector

VIII. To bring entire country under electrification by the year 2020.

IX. To ensure reliable supply of energy to the people at reasonable and affordable price.

X. To develop a regional energy market for rational exchange of commercial energy to ensure energy security.

The power policy included in the NEP has set policies for load management and conservation which include,

i. The use of Fluorescent tube lights / compact fluorescent tube lights (CFL) and energy saving bulbs are to be encouraged in place of incandescent lamps resulting in significant reduction in system demand.

ii. The utilities, local R and D and educational institutions shall undertake a joint survey to identify measures of conservation at the end-use level. Consumers will be motivated to adapt such identified measures.

iii. Commercial banks should be encouraged to provide loans at softer terms for implementation of conservation measures at the end-use level.

The objectives of 'Renewable Energy Policy, 2008' are to:

I. Harness the potential of renewable energy resources and dissemination of renewable energy technologies in rural, peri-urban and urban areas;

II. Enable, encourage and facilitate private sector investment in renewable energy projects;

III. Develop sustainable energy supplies that can substitute for indigenous non-renewable energy supplies as they are being depleted; and

IV. Scale up contributions of renewable energy to electricity production.

V. Scale up contributions of renewable energy to electricity and heat energy.

VI. Promote appropriate and efficient use of renewable energy.

The draft 'Energy Conservation Act 2008' has a chapter on 'Building Related Energy Code' which include codes relating to adoption of passive solar techniques in building construction, mandatory insulation requirements, integration of rain water harvesting provision, use of renewable energy sources in commercial and apartment buildings, use of energy efficient light fixtures, use of energy efficient building materials etc.

1.7 Research Methodology

Having reviewed available information and related works done by other researchers, this section narrates how the thesis was conducted

1.7.1 Typology of the research

This thesis is situated in the domain of descriptive and causal research. The research is aimed to provide insight into the research problem - the final energy consumption profile of apartment type residential buildings in Dhaka city in the face of energy crisis in the country. This is done by focusing the natural lighting condition in the interior spaces and internal thermal comfort which are assumed to be affected by the surrounding urban texture and ambient thermal environment The research also examined the potential cause and effect relationships between the different selected variables of interest depicted below. A correlation study is done to find out the type and strength of associative relationships among these variables.

The independent variables of this research are; the surrounding urban texture and ambient environment of the building in question, which are quantified by;

I. The ratio of open space and built up area and
II. The ratio of green coverage and exposed hard surface area and outdoor ambient temperature.

The selected dependant variables are;

I. The internal light level,
II. Indoor- outdoor temperature difference and
III. The energy efficiency of the building in terms of unit of electricity consumed per square meter space per annum

The following sections depict the methodology by explaining step by step activities that were carried out under this research while Figure 1.6 presents the research methodology in the form of a 'flow diagram'.

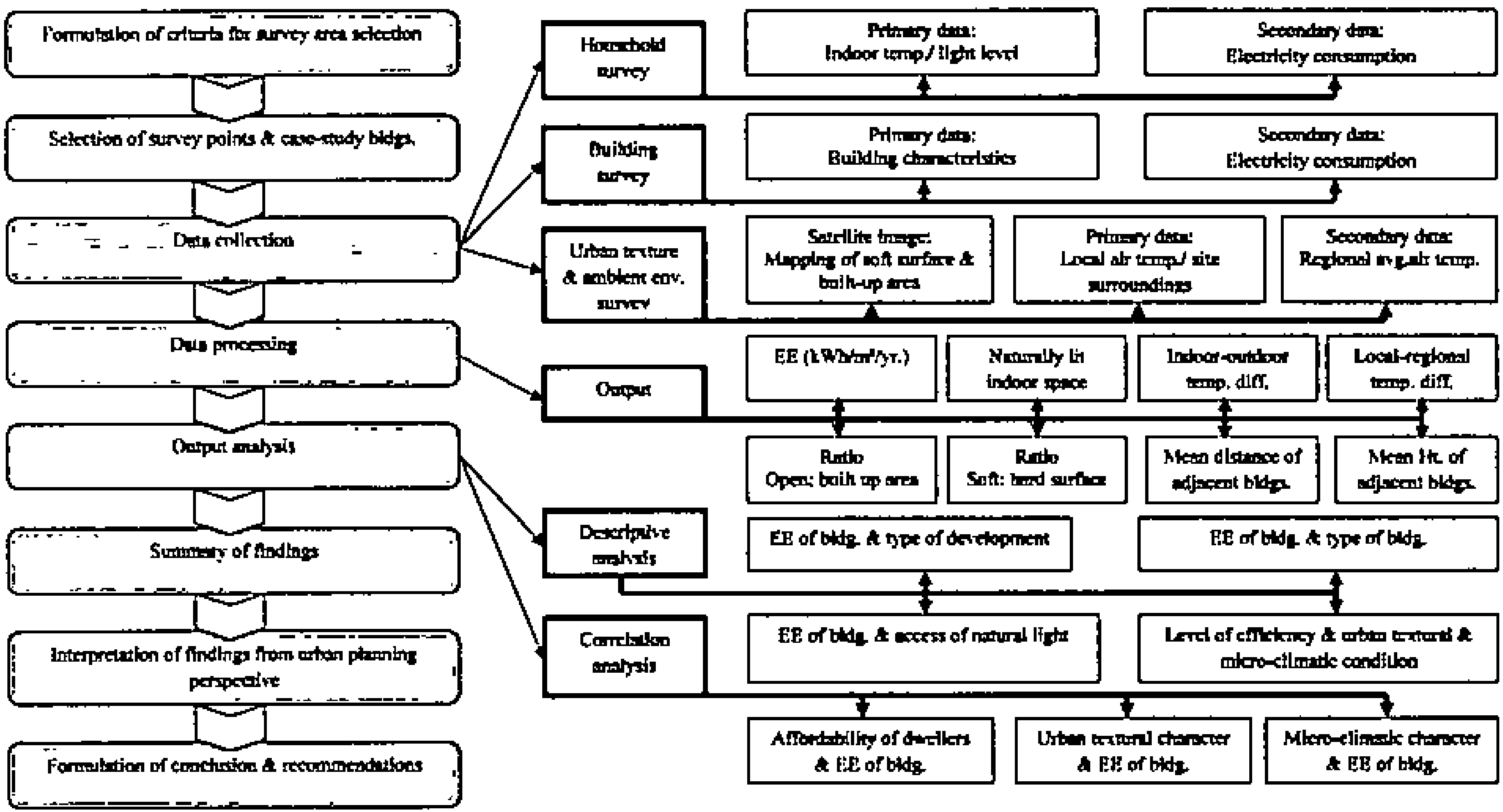

Figure 1.6: Research Methodology at a Glance

1.7.2 Research activities

The step by step activities that were carried out to conduct the research is explained in the following sections.

1.7.2.1 Selection of Case Study Areas and Case Study Buildings

To determine the final energy use in the form of electricity in residential buildings of Dhaka and to examine the relationship between 'energy efficiency' of these buildings and their surrounding urban texture and ambient environment, the study was delimited to apartment type residential buildings located within Dhaka City Corporation (DCC) area. 11 long established and prominent residential areas were selected as 'case study areas' for this study. They are,

I. Uttara, sector 1 and 6
II. Mirpur
III. Kalyanpur
IV Gulshan
V. Dhanmondi residential area
VI. Lalmatia
VII. Rajabazar
VIII Shegunbagicha
IX. Shantinagar
X. Teachers' quarter of Dhaka University
XI. Teachers' quarter of BUET

The selection criteria for the 'case study areas' are as follows;

I. The land use pattern of the area should be predominantly of residential kind.
II. The areas should represent both planned and unplanned type of residential development existing in Dhaka city.
III. The case study areas should include both private sector and non-private i.e government or semi-government sector residential developments
IV. The areas should consist apartment-type residential buildings both walk-up and multi-story buildings with lifts.
V. As affordability is a prime factor that affects energy end use in households, areas occupied by households of similar affordability were chosen. For this research, the upper middle to high income group was targeted Household

classification by different income range and their distribution has been estimated by Islam, 2005 shown in table 1.4.

Table 1.4: Income Group and Their Distribution in Dhaka (DCC)

Income group	Monthly Household Income (US $*)	Households	
		Percent	No.
Higher middle	374-746	13	143,910
Lower high	747-1492	5	55,350
Higher	1493+	2	22,140

Source: Islam, 2005 * US$ 1 = 69 BD Taka (2007 value)

The selection criteria for case study buildings:

I. The buildings should represent the existing design trend of apartment type residential buildings.

II. The buildings should be accessible and occupants should be cooperative.

III. Required building information and household energy consumption records is available.

1.7.2.2 Delineation of 'survey points'

A 'Survey point' for this study is an arbitrarily selected area of specific extent within a case study area which contains one or more 'case study buildings'. An imaginary boundary is delineated to represent the catchment area for a particular group of case study buildings and surveyed in order to express the surrounding urban textural quality in quantifiable terms, such as;

- Ratio of open space and built-up area,
- Ratio of green coverage and exposed hard surface,
- Ratio of mean distance and mean height of adjacent buildings.

As there was no reference found on the extent of catchment area that has substantial and detectable impact on a building situated in an urban area, the study is done by fixing a boundary of 200m radius i.e an area of .2km^2 with the case study building or buildings in question situated centrally.

1.7.2.3 Sample size determination

a. Sample size of building survey

There is no reliable and updated data on the actual number of residential apartment buildings in D.C.C area. According to REHAB, the private sector real estate and housing association of Bangladesh, approximately 56000 apartment units were delivered by the developers in the last 20 years (http://www.rehab-bd.org) . However. the number of total apartment type buildings cannot be assumed from this information because, the number of apartment unit per building varies widely and also there are many apartment type residential buildings which area constructed by individual land owners themselves and the public sector.

For this research, 30 apartment buildings with easy access were selected as case study buildings as it was considered feasible to carry out the survey by a single researcher with limited resources.

b. Sample size for household survey

In order to determine the electricity consumption per unit floor area and to collect information on internal lighting and thermal environment of the case study buildings, a household survey was done. The total number of households dwelling in the case study buildings was 432. According to a general statistical method of random sampling described by Salant et al. 1994 and Rea et al, 1997, the required sample size comes in between 110 and 141 households with ±7% sampling error and 95% confidence level. The survey was done in 112 households.

1.7.2.4 Primary data collection

Primary data collection was done in two ways to collect information on the physical environment of the 'survey points' and related information on electricity consumption of the building and individual apartment units. They are physical survey by observation, instrumental measurement and questionnaire survey. The primary survey was carried out within four months period from mid August, 2009 to mid November. 2009.

a. Physical /field survey

A data checklist for physical survey was developed (annexure A2). Instrumental measurements for light-levels. temperature and humidity levels were done in a particular segment of the day, which is within 10:30am to 1:30 pm. This is maintained to create a logical basis for comparing micro level data among different survey points and also with the regional average Internal readings were taken from apartment units located in either mid-level floors of a building or both lower and upper level floors of a building to get an average scenario for the whole building.

b. Questionnaire survey

The questionnaire survey was mainly focused to get a general profile of the household, the consumption characteristic related to use of electrical equipments needed for lighting and thermal comfort. To find out the consumption for building utility and services like lift, water supply, lighting of common spaces etc. a separate questionnaire was developed (annexure A2).

1.7.2.5 Secondary data collection

The secondary data collection focused on the information of household electricity consumption from the monthly electricity bills for a whole year. It was ensured that monthly bills of both warmer and cooler months are collected to obtain a comprehensive estimation of consumption considering the seasonal variations. The bills were collected from the same group of households who were surveyed with instrumental measurement and questionnaires. Building plans, publicly published area maps showing land use and holding numbers and satellite images of case study areas from 'Google Earth' were collected to examine the urban texture.

1.7.2.6 Calculation of energy efficiency (kwb /m²/yr.) of a building

The calculation of energy efficiency of a particular building has been done by using the following formula;

$$EE = \frac{X*12+Y*\text{total no. of floors}*12}{\text{Total floor area of the building}}$$

Where; EE = KWh/m²./yr.

X = Avg. unit(KWh) consumed for common utility services of a building in a month

Y = Avg. total unit(KWh) consumed in individual apartments located on one floor in a month.

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1.7 2.7 Analysis of satellite image of case study areas

The ratio of open space and built-up area in a particular 'survey point' has been calculated by analyzing the vector reproduction of the image of the particular area taken from the satellite image from 'Google Earth'. The vector reproduction had been done by using the software 'AutoCad 2000'

The ratio of green coverage and exposed hard surface of a particular 'survey point' has been calculated by analyzing the vector reproduction of the satellite image of the particular area taken from the 'Google Earth'.

Estimation of open area, built up area and green coverage from a satellite image done in this method does not give the actual area but it gives a result close enough for establishing an average scenario of a particular survey point and allows comparison among the selected areas.

1.7.2.8 Techniques used for data analysis

Quantitative data analysis for corelation studies and descriptive analysis has been done by using 'SPSS 12.0'. The graphical data analysis has been done by using 'Corel draw 12.0' and 'AutoCad 2000'.

1.7.2.9 Interpretation of survey findings from urban planning point of view

After analyzing the survey results. the findings were interpreted and explained in order to identify their implications in the existing urban context and the conclusions that can be drawn regarding energy performance of residential buildings in varying location context.

CHAPTER 2:

CASE STUDY ANALYSIS

2.1 Introduction

The context and relevance of studying energy consumption in residential buildings of Dhaka have been stated in Chapter 1 along with the importance of improved energy efficiency in urban planning context to ensure sustainable urban development in our country and the existing barriers and policy measures applied in Bangladesh and other countries regarding the same. The following sections of this Chapter present the case studies of residential apartment buildings in Dhaka city area regarding the consumption of final energy in the form of electricity.

As mentioned earlier in Chapter 1, section 1.7.2, a total of 30 residential apartment buildings were taken as case studies from 11 different residential areas of Dhaka City Corporation area. About 11 of the case study buildings are apartments with lift and the rest 19 buildings are walk-up apartments. A structured questionnaire survey was carried out among the households dwelling in the apartment buildings to get information on their electricity consumption. A primary physical survey had been done to get information on indoor and immediate outdoor physical environment. Moreover, to study the surrounding urban texture, an area of .1sq.km was demarcated around the case study buildings referred to as 'survey points'. Then, the satellite images of the corresponding survey points taken from 'Google Earth' were analyzed two-dimensionally to derive the amount of built up area as opposed to open space and the amount of soft surface cover as opposed to exposed hard surface cover within the boundaries of each survey point. Finally the quantitative findings of the survey were summarized and analyzed to derive a base line scenario of energy consumption in apartment buildings and the correlation among parameters selected for this study.

2.2 Case Study Areas

Based on their development pattern, the case study areas can be classified under three categories, they are: planned private development, un-planned private development and planned public housing. The planned residential areas of Dhaka where land developments were done by Government authority were taken as case studies for this research leaving out the planned residential areas by private developers. In this specifically for residential land use but the construction were done by private sector i.e. individual plot owner or private construction companies, are termed as the 'planned private development'. While the planned residential areas where public housing facilities has been provided for different target groups such as government employees, different professional groups, etc. in the form of rent or lease are termed as 'planned public housing development'. The third type of residential development is usually found to be grown organically in mixed land use areas without any prior planning. The land development and construction both are done by the private sector in this type of developments and are termed in this research as the 'un-planned private developments'. Table 2.1 shows the case study areas under each category. Figure 2.1 shows the distribution of case study buildings in different type of case study areas.

Table 2.1: Classification of Case Study Areas

	Planned private		Un-planned private		Planned public housing
1	Uttara model town(sector1 and sector 6)	5	Rajabazar	9	Kalyanpur Housing Estate
2	Gulshan residential area	6	Dhanmondi	10	Shahid Giasuddin R/A, Dhaka University
3	Mirpur	7	Shegun Bagicha	11	BUET Teachers' Quarters, (Dhakeswari campus)
4	Lalmatia	8	Shanti Nagar		

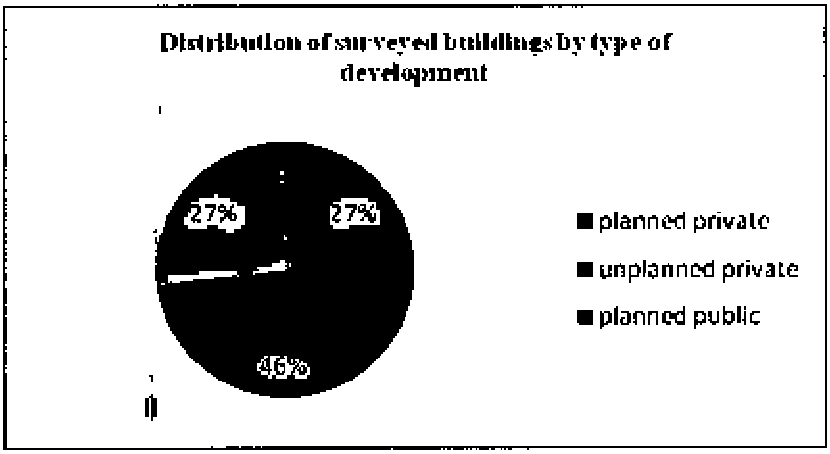


Figure 2.1: Distribution of Surveyed Buildings by Type of Residential Developments.

Plate 2.1: 'Survey Point' Locations in Google Earth Image of Dhaka, Bangladesh.

2.3 Urban Texture and Ambient Environment of Case Study Areas

The urban texture of the selected survey points were analyzed by two quantifiable parameters of the respective physical environment; they are,

- The ratio of 'open space' and 'built-up area'; the calculation was done by a 2-D analysis of the satellite image of the respective area The roofed area is demarcated as 'built up area' and the rest which includes un-built area, roads and water bodies are combinedly measured as 'open space'.
- The ratio of 'green coverage' and 'exposed hard surface'; the total area as seen in the satellite image is divided into two separate type of surface. All areas covered with large tree foliage (including building roofs covered under large trees), vegetated and exposed soil, are demarcated as 'green coverage'. On the other hand, the rest is 'exposed hard surfaces' which include exposed paved area, roads and building roofs. In such survey points where water bodies are present, the term 'soft surface' is used combinedly with green areas.

The ambient environment is described by the thermal condition in indoor spaces, immediate outdoors and the difference with the regional average at the same date and time for each survey points.

2.3.1 Planned private developments; Uttara, Mirpur, Gulshan and Lalmatia

In Uttara, Mirpur, Gulshan and Lalmatia, land development was done by the public sector for residential land use and then allotted to individual plot owners where buildings have been constructed by them or real –estate developer companies. Uttara is mainly occupied by the retired government employees. Residents of Gulshan are mainly high income group and Mirpur and Lalmatia is occupied by higher middle and lower high income households. Plots of typical sizes laid along the regular street network create the common feature among all of these areas. Table 2.2 shows the survey results from primary physical survey and texture analysis from satellite images of all the survey points under this category.

Survey points at Uttara, Gulshan and Lalmatia area are similar in their characteristics as they all are laid in a strong grid –iron pattern street layout. Heights of the residential buildings vary within the range of single story to 6 stories. These areas have higher proportion of open spaces. Mirpur survey point on the other hand is the most congested under the planned private category. It is also the earliest residential development among the four. Although the proportion of open space is lower, vegetation coverage is the highest in Mirpur area compared to the other areas. Lamatia area has the lowest vegetation cover which means the area has the highest proportion of exposed hard surface among all areas in this category.

Both the survey points at Gulshan area have the benefit of having the Gulshan and Banani Lake in proximity while the other areas of this category do not have large water bodies near except Lalmatia survey area where a medium sized pond is located. These water bodies could be the likely reason for cooler ambient conditions with respect to the regional average in Lalmatia and Gulshan survey points as found in the survey. Mirpur and Uttara survey points showed higher ambient temperature than the Dhaka city average on the survey date which can be the result of higher proportion of exposed hard surfaces and lack of water bodies in these areas. Although to prove this as a normal trend, multiple readings of temperature throughout a longer time span would be needed.

Table 2.2: Urban Texture and Ambient Temperature of Survey Points in Planned Private areas

Location	Survey point	Open space : built-up area	Green cover : exposed hard surface	Type of case study bldg	Survey month	Immediate outdoor temp. (at the time of survey) I	Regional avg. temp.* (at the time of survey) R	Temp difference (I-R)
Uttara	U-1	3.3	0.5	Walk-up	Oct	29.5 °C	26.2 °C	3.3 °C
	U-2	1.8	0.59	Aptt. with Lift	Sep	27.4 °C	26 °C	1.4 °C
Mirpur	M-1	0.77	0.83	Walk-up		-	-	-
				Aptt. with Lift		-	-	-
Gulshan R/A	G-1	2	0.7	Walk-up	Nov	23 °C	27.2	- 4.2°C
	G-2	1.7	0.5	Aptt. with Lift		-	-	-
Lalmatia	L-1	1.9	0.4	Walk-up		-	-	-
				Aptt. with Lift	Nov	23°C	26°C	-3 °C

Note: * The regional average temperature data of the same date and time with the corresponding survey measurements was collected from *Russia's Weather Server* >> *Weather Archive* >> *Asia* >> *Bangladesh* >> *Dhaka (041923)*, *URL: http://meteo.infospace.ru*

Figures from 2.2a,b,c,d, to 2.7a,b,c,d present the graphical representation of the urban texture of the survey points located at Uttara, Mirpur, Gulshan and Lalmatia.

Plate 2.2: Location of 'Survey point U-1': 'Google Earth' image

Planned private development: Uttara (sector 1)

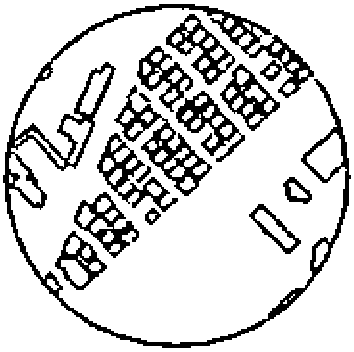


Figure 2.2a: Built-up area within U-1

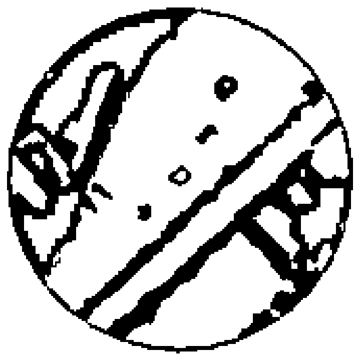


Figure 2.2b: Green coverage within U-1

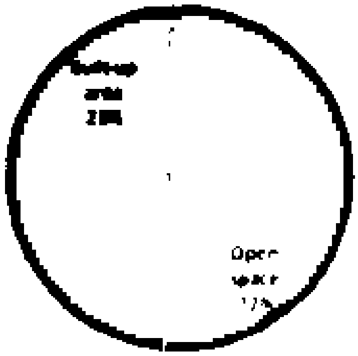


Figure 2.2c: Open space and built-up area ratio at U-1

Figure 2.2d: Green coverage and exposed hard surface ratio at U-1

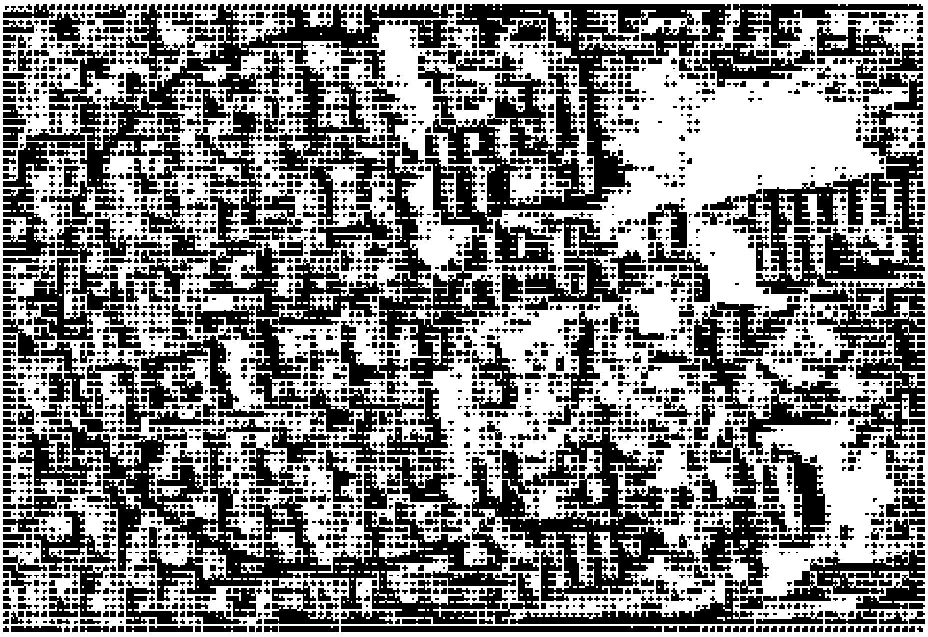


Plate 2.3: Location of 'Survey point U-2': 'Google Earth' image

Planned private development: Uttara (sector 6)

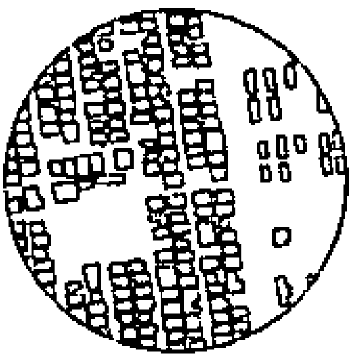


Figure 2.3a: Built-up area within U-2 boundary

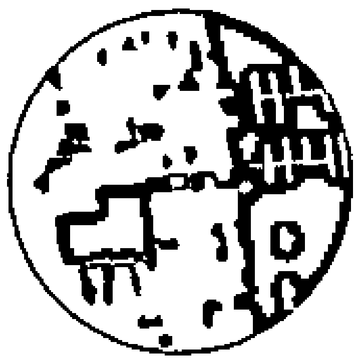


Figure 2.3b: Green coverage within U-2 boundary

Figure 2.3c: Open space and built-up area ratio at U-2

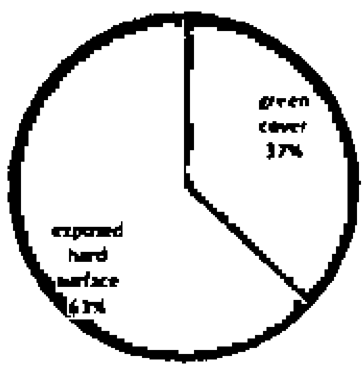


Figure 2.3d: Green coverage and exposed hard surface ratio at U-2

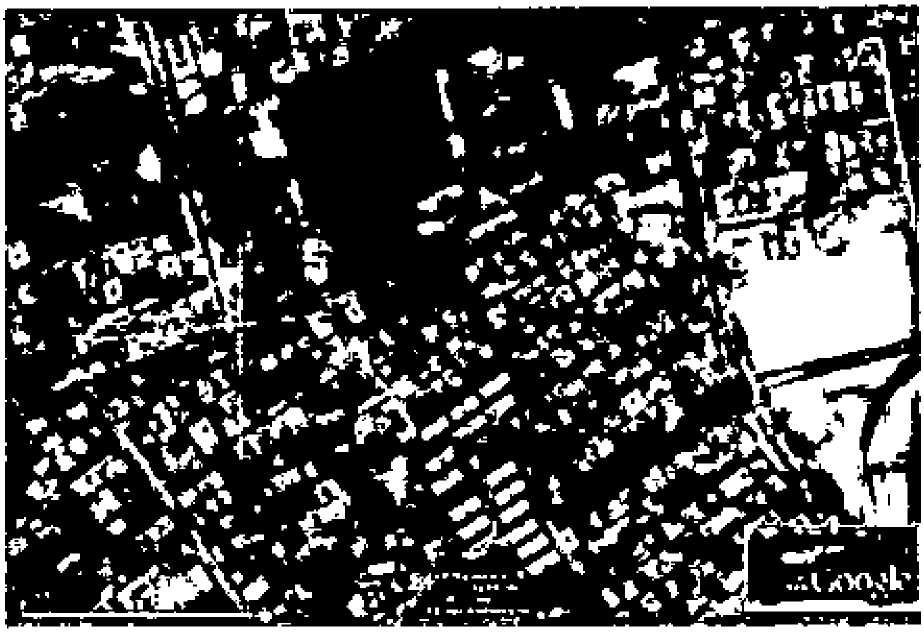


Plate 2.4: Location of 'Survey point M-1': 'Google Earth' image Planned private development: Mirpur

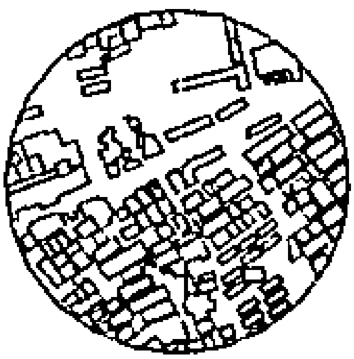


Figure 2.4a: Built-up area within M-1

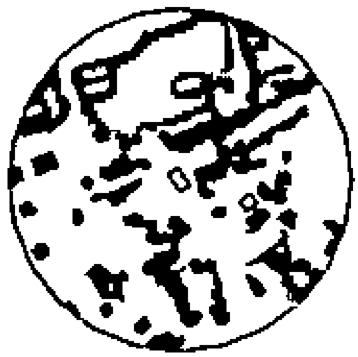


Figure 2.4b: Green coverage within M-1

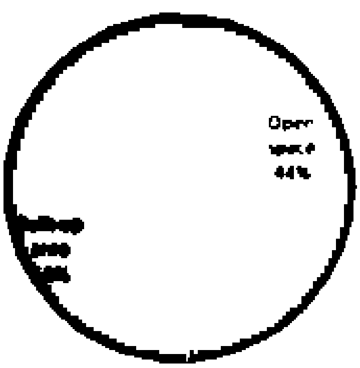


Figure 2.4c: Open space and built-up area ratio at M-1

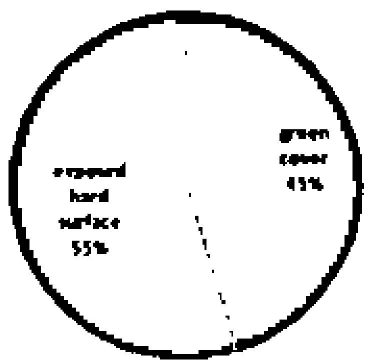


Figure 2.4d: Green cover and exposed hard surface ratio at M-1

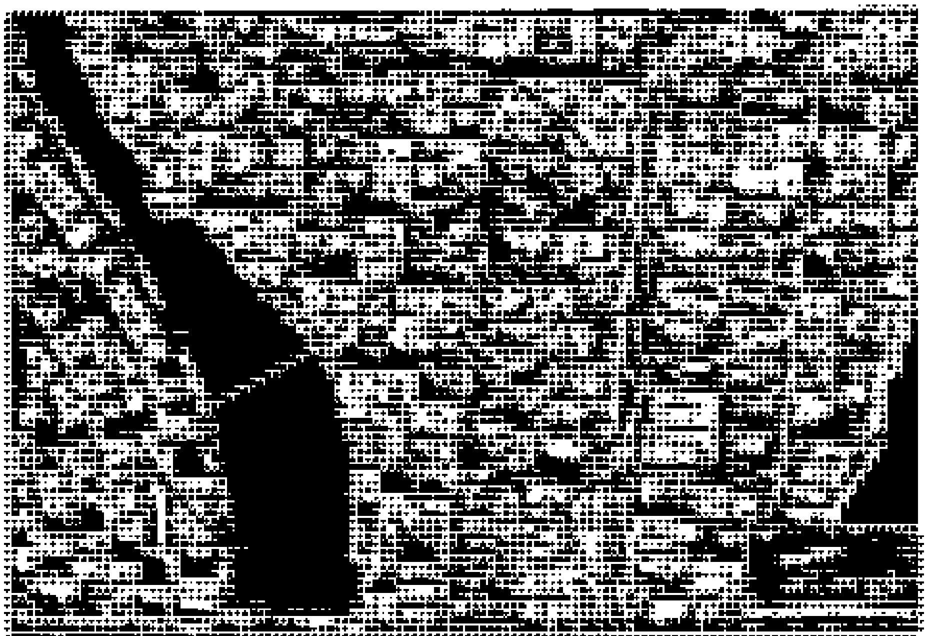


Plate 2.5: Location of 'Survey point G-1': 'Google Earth' image
Planned private development: Gulshan

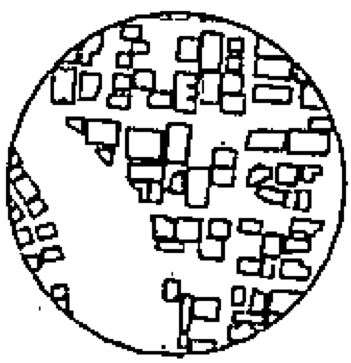


Figure 2.5a: Built-up area within G-1

Figure 2.5b: Soft surface within G-1 boundary

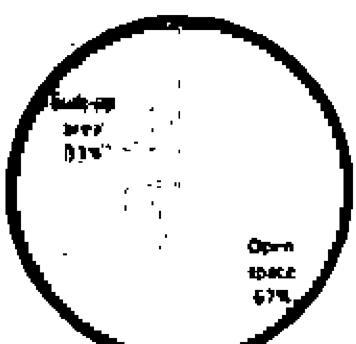


Figure 2.5c: Open space and built-up area ratio at G-1

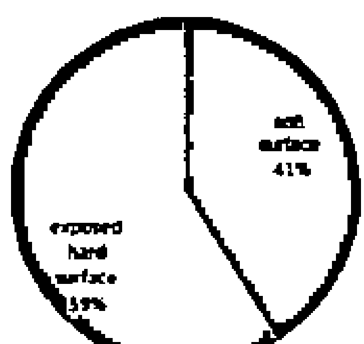


Figure 2.5d: Soft surface and exposed hard surface ratio at G-1

Plate 2.6: Location of 'Survey point G-2': 'Google Earth' Image

Planned private development: Gulshan

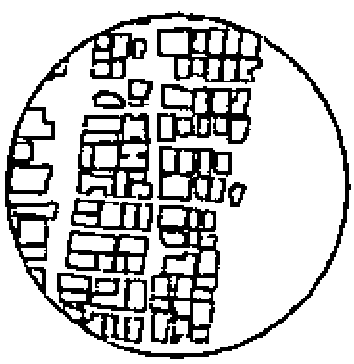


Figure 2.6a: Built-up area within G-2

Figure 2.6b: Soft surface within G-2 boundary

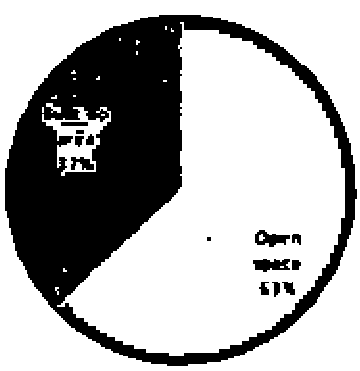


Figure 2.6c: Open space and built-up area ratio at G-2

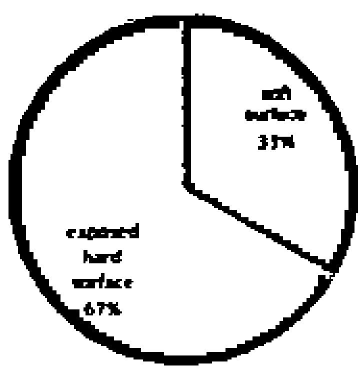


Figure 2.6d: Soft surface and exposed hard surface ratio at G-2

Plate 2.7: Location of 'Survey point L-1': 'Google Earth' image

Planned private development: Lalmatia

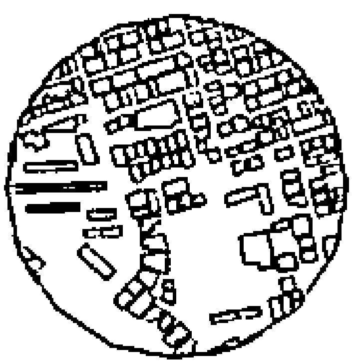


Figure 2.7a: Built-up area within L-1

Figure 2.7b: Soft surface within L-1 boundary

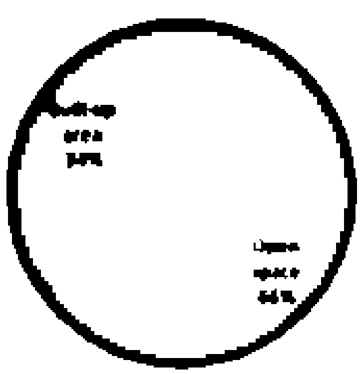


Figure 2.7c: Open space and built-up area ratio at L-1

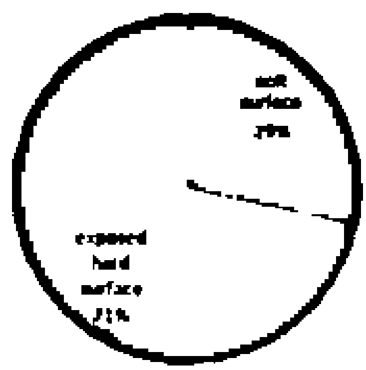


Figure 2.7d: Soft surface and exposed hard surface ratio at L-1

2.3.2 Unplanned private developments: Rajabazar, Dhanmondi, Shegun Bagicha and Shanti Nagar

Residential developments in Rajabazar, Shegunbagicha and Shantinagar area had grown in a spontaneous pattern with high density because of their unique locations. Rajabazar is adjacent to the Farmgate area which is a very important mass communication junction and a commercial centre. Shegunbagicha was primarily a commercial and institutional zone where various government and semi-government offices are situated and the residential area of diplomats and high government officials in baily road is also not very far. People have to come here for work, therefore, growing demand for accommodation near work has been the key factor for the conversion of low density sparsely situated residential lands into high density apartment housing developments. Shantinagar also enjoys the proximity of the educational institutes situated at Bailey Road from very early days and the thriving commercial center and mass communication junction at Khilgaon-Malibagh area from where communication towards the Old CBD at Motijheel and the New CBD at Mohakhali-Gulshan-Banani is very convenient. More or less, the residential development in these areas can be characterized by infill developments with congested road network of organic pattern.

The case of Dhanmondi is totally different from the areas discussed above. The area is primarily one of the most prominent planned residential areas of Dhaka city with fixed plot sizes and organized road network, although a major portion of the residential buildings are now being occupied by commercial establishments But the portion of Dhanmondi that has been selected as case study area here is very much different in its pattern of development than the rest of Dhanmondi. Flanked with the high profile route of 'Mirpur road' in the east and the 'Road 27' in the north, buildings in this pocket does not conform to the height restriction followed elsewhere in Dhanmondi. Therefore high density apartment buildings of different height constructed along both sides of narrow lanes make up a contrasting scenario compared to the rest of the Dhanmondi area.

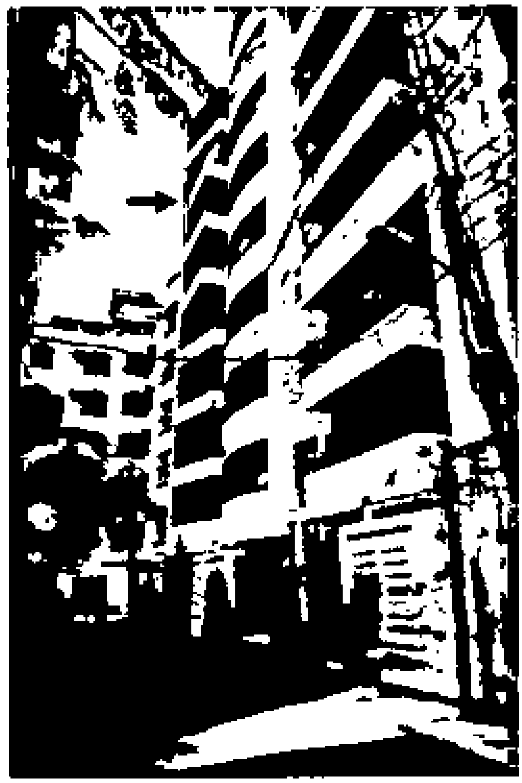
The common feature of the survey points under this category is higher proportion of roofed area and negligible vegetation coverage. According to the survey results, on average almost half of the land surface is covered by buildings or other types of structures in all the four areas (see figures from 2.8 a, b, c & d to 2.14 a, b, c &d). As buildings are very closely located, they cast shadows on each other and on the narrow internal road surfaces. Most of the building facades and road surfaces do not get any sunlight during the first half of the day. During the field survey this type of situation was observed at the survey points of Rajabazar and Dhanmondi and also at survey point SB-1 of Shegunbagicha. This may be a reason for the outdoor spot measurements of the air temperature being much less than the regional average at the same time (see table 2.3).

Table 2.3: Urban Texture and Ambient Environment at Survey Points of Unplanned Private Developments

	Survey point	Open space - built-up area ratio	Green cover - exposed hard surface ratio	Type of case study bldg	Survey month	Immediate outdoor temp. (at the time of survey) I	Regional avg. temp.* (at the time of survey) R	Temp diff. (I- R)
Rajabazar	R-1	2	0.4	Walk-up	Nov	23°C	23°C	0°C
	R-2	0.5	0.2	Walk-up	Nov	22°C	25.4°C	-3.4°C
				Aptt with Lift	Nov	22°C	25.4°C	-3.4°C
Dhanmondi	D-1	1.2	0.2	Walk-up	Nov	24.8	27.2	-2.4°C
				Walk-up	-	-	-	-
				Aptt with Lift	Aug	29.5	25.4	4.1°C
				Aptt. with Lift	Nov	23	25	-2°C
Shegun-bagicha	SB-1	1.3	0.1	Walk-up	Sep	30	33.3	-3.3°C
				Walk-up	Sep	30	33.3	-3.3°C
				Walk-up	Sep	30	33.3	-3.3°C
				Aptt. with Lift	-	-	-	-
	SB-2	1.25	0.13	Aptt. with Lift	Sep	29.8	29.7	1°C
Shantinagar	S-1	0.9	0.1	Walk-up	-	-	-	-
	S-2	1.3	0.1	Aptt. with Lift	-	-	-	-

Note: * The regional average temperature data of the same date and time with the corresponding survey measurements is collected from *Russia's Weather Server* >> *Weather Archive* >> *Asia* >> *Bangladesh* >> *Dhaka (#41923), URL: http://meteo.infospace.ru*

2.1a: Case study of 'Walk-up' type bldg.



2.1b: Case study of 'Apartment bldg. with lift'

2.1c: Case study of 'Apartment with lift'

2.1d: Case study of 'Apartment with lift'

Picture 2.1: Exterior view of surveyed buildings at 'Survey point D-1' at Dhanmondi; Densely situated apartment buildings of different height constructed along both sides of narrow lanes, obstructing sunlight from each other.

2.2a: Case study of multi-rise 'Apartment with lift'

2.2.b: Case study of 'Walk-up' type bldg.

2.2c: Case study of 'Walk-up' type bldg

Picture 2.2: Exterior view of surveyed buildings at 'Survey point SB-1 & SB-2 at Shegun Bagicha; Higher proportion of built-up area and lack of vegetation cover.

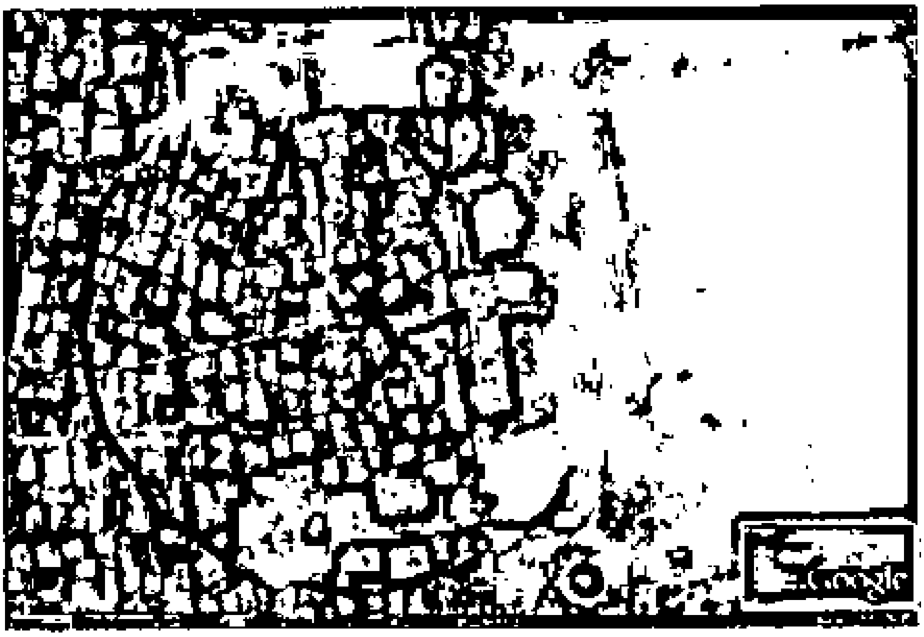


Plate 2.8: Location of 'Survey point R-1': 'Google Earth' Image

Unplanned private area: Razabazar

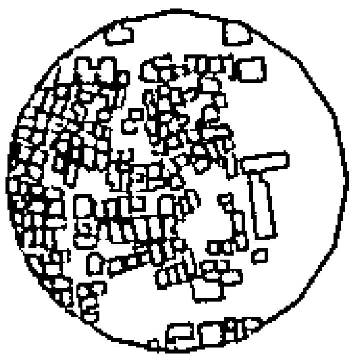


Figure 2.8a: Built-up area within R-1

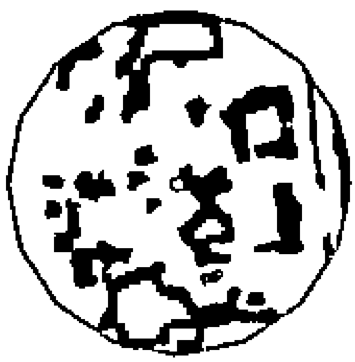


Figure 2.8b: Green coverage within R-1

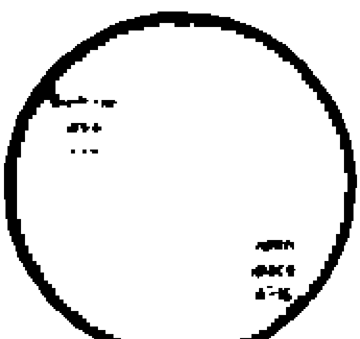


Figure 2.8c: Open space and built-up area ratio at R-1

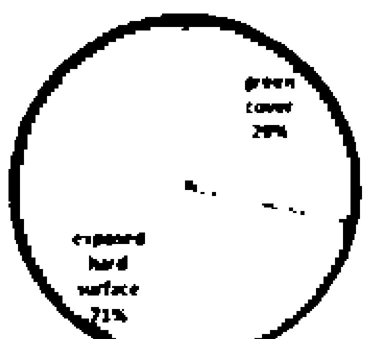


Figure 2.8d: Soft surface and exposed hard surface ratio at R-1

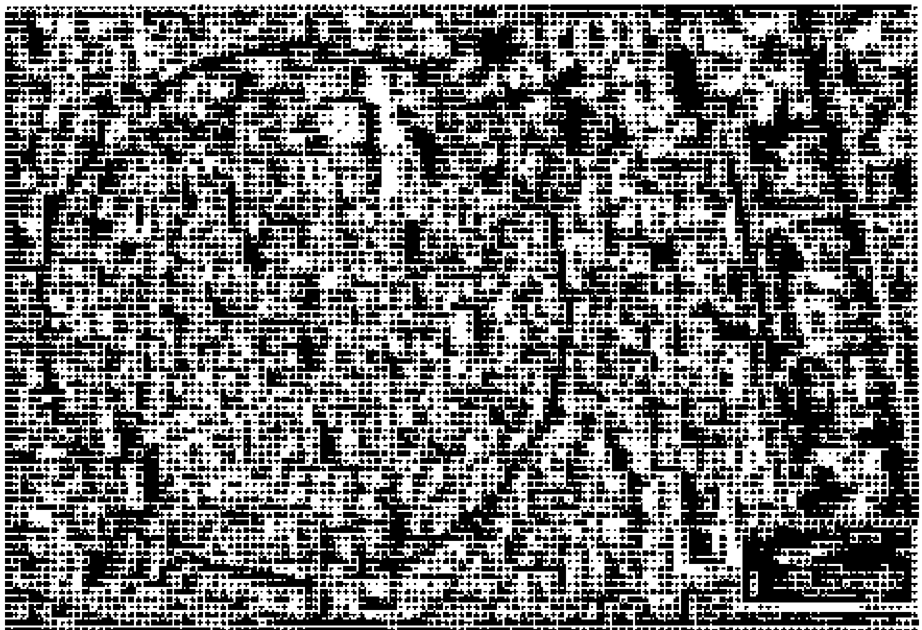


Plate 2.9: Location of 'Survey point R-2': 'Google Earth' image

Unplanned private area; Razabazar

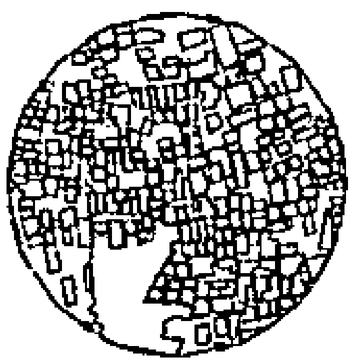


Figure 2.9a: Built-up area within R-2

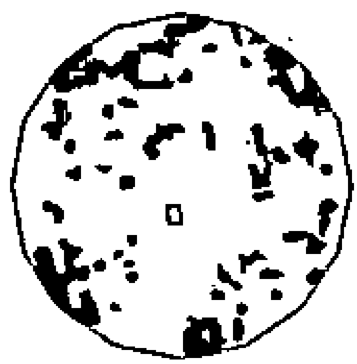


Figure 2.9b: Soft surface within R-2 boundary

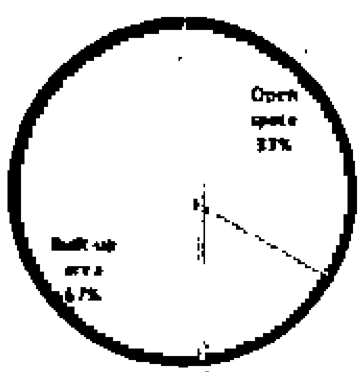


Figure 2.9c: Open space and built-up area ratio at R-2

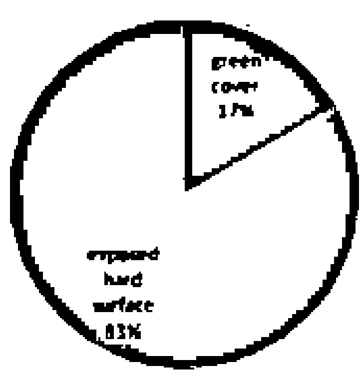


Figure 2.9d: Soft surface and exposed hard surface ratio at R-2

Plate 2.10: Location of 'Survey point D-1': 'Google Earth' image

Unplanned private area: Dhanmondi

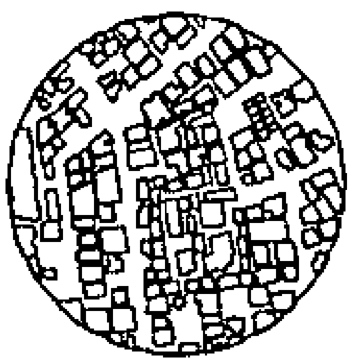


Figure 2.10a: Built-up area within D-1

Figure 2.10b: Soft surface within D-1 boundary

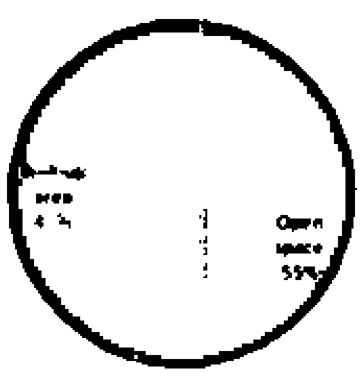


Figure 2.10c: Open space and built-up area ratio at D-1

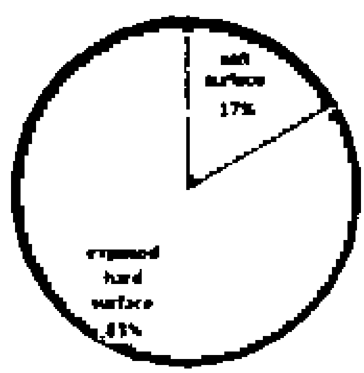


Figure 2.10d: Soft surface and exposed hard surface ratio at D-1

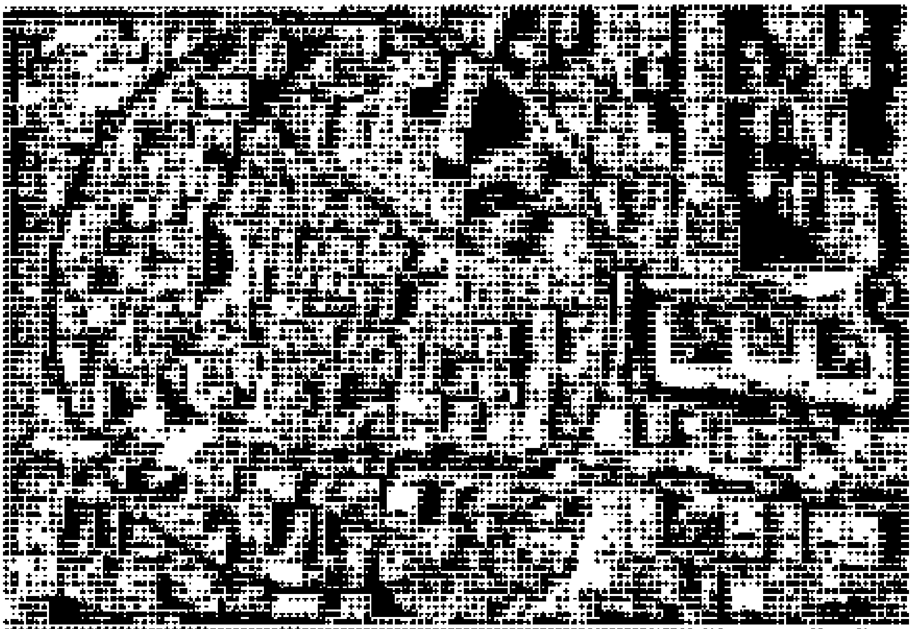


Plate 2.11: Location of 'Survey point Sb-1': 'Google Earth' image

Unplanned private area: Shegunbagicha

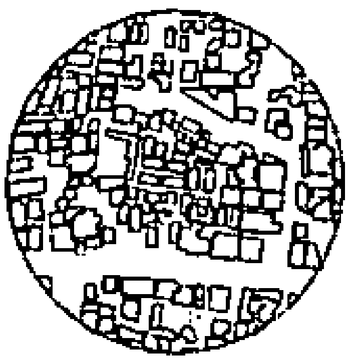


Figure 2.11a: Built-up area within Sb-1

Figure 2.11b: Green coverage within Sb-1

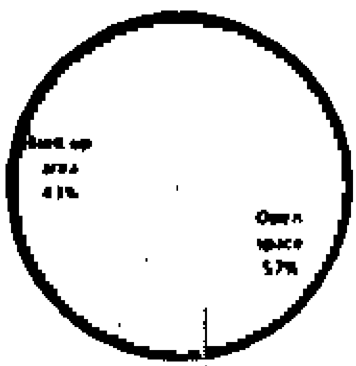


Figure 2.11c: Open space and built-up area ratio at Sb-1

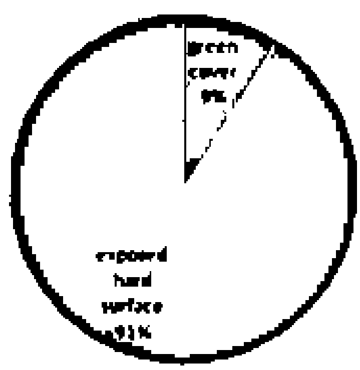


Figure 2.11d: Green cover and exposed hard surface ratio at Sb-1

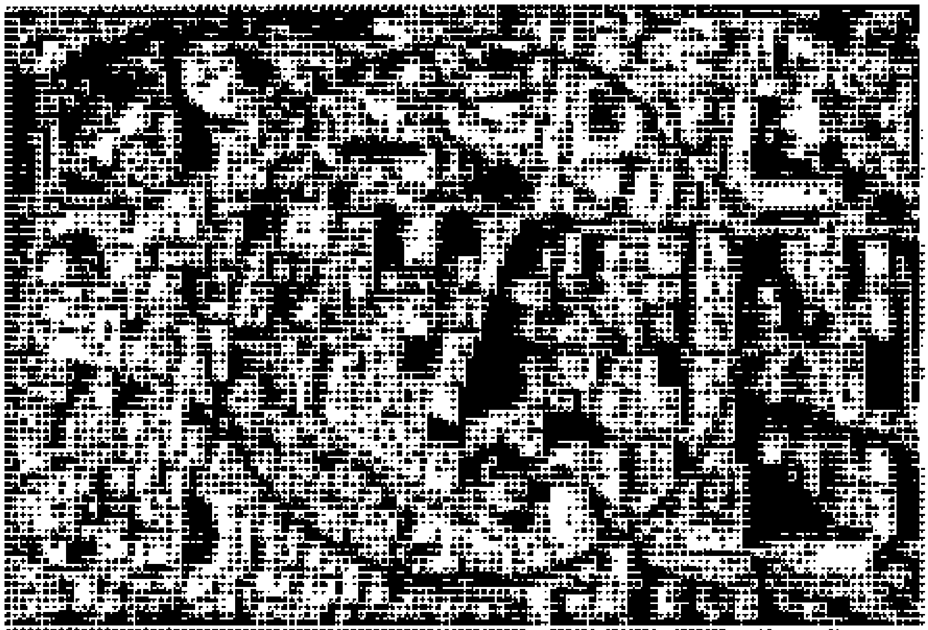


Plate 2.12: Location of 'Survey point Sb-2': 'Google Earth' image

Unplanned private area: Shegunbagicha

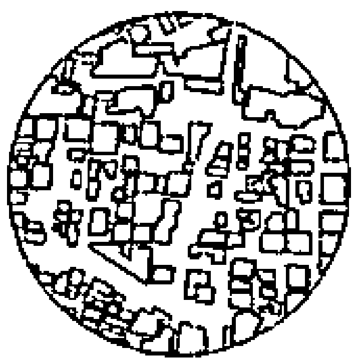


Figure 2.12a: Built-up area within Sb-2

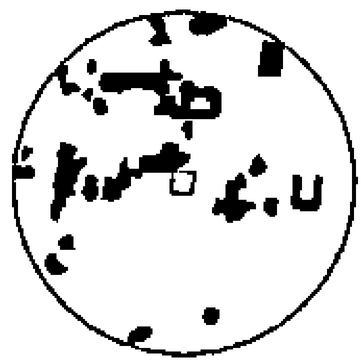


Figure 2.12b: Green coverage within Sb-2

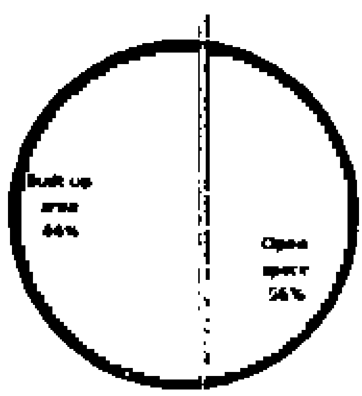


Figure 2.12c: Open space and built-up area ratio at Sb-2

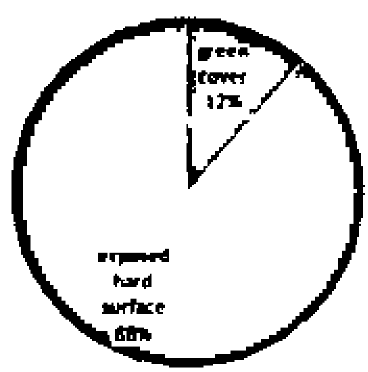


Figure 2.12d: Green cover and exposed hard surface ratio at Sb-2

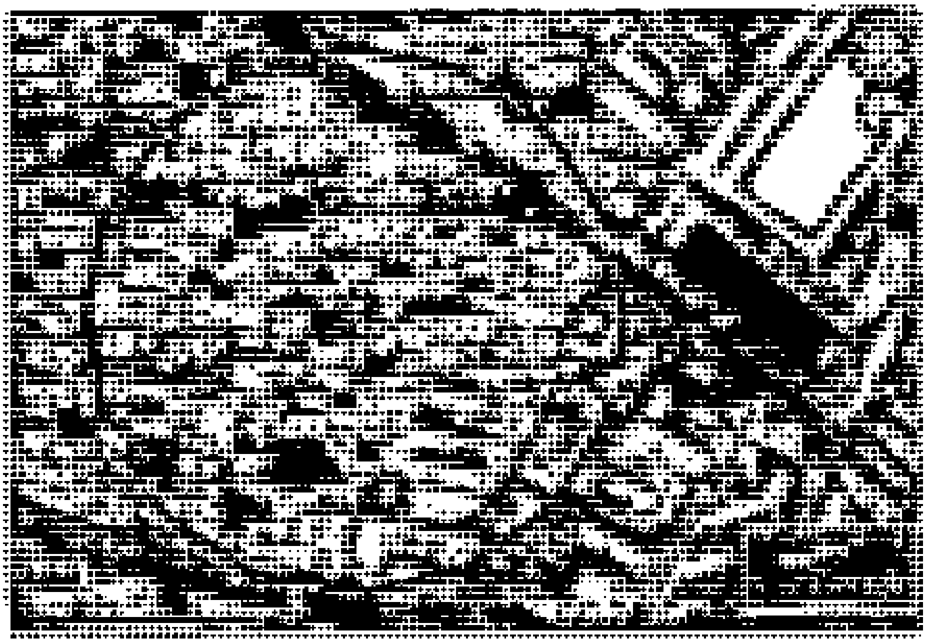


Plate 2.13: Location of 'Survey point S-1': 'Google Earth' image unplanned private development: Shanti Nagar

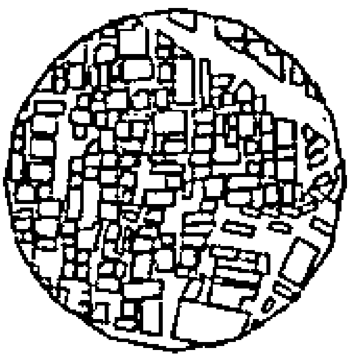


Figure 2.13a: Built-up area within S-1

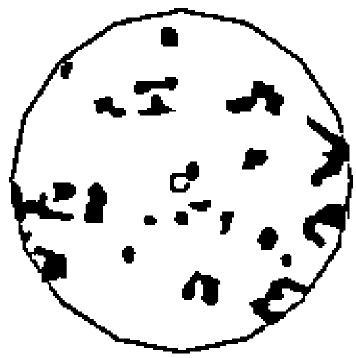


Figure 2.13b: Green coverage within S-1

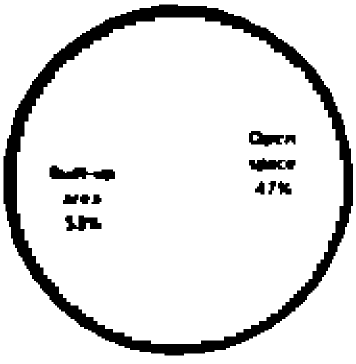


Figure 2.13c: Open space and built-up area ratio at S-1

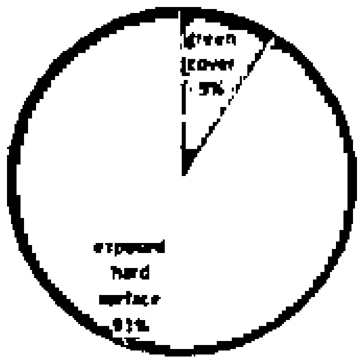


Figure 2.13d: Green cover and exposed hard surface ratio at S-1

Plate 2.14: Location of 'Survey point S-2': 'Google Earth' image Unplanned private development: Shanti Nagar

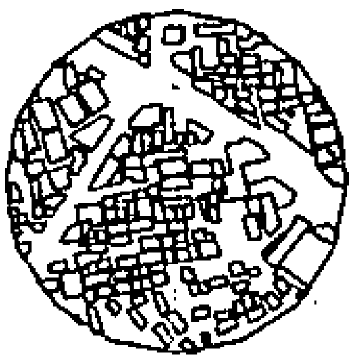


Figure 2.14a: Built-up area within S-2

Figure 2.14b: Green coverage within S-2

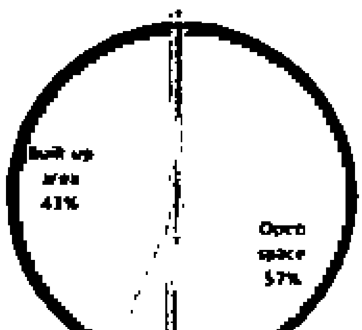


Figure 2.14c: Open space and built-up area ratio at S-2

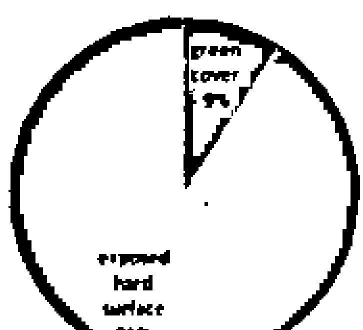


Figure 2.14d: Green cover and exposed hard surface ratio at S-2

2.3.3 Planned public housing: Kalyanpur housing estate, Shahid Giasudding residential area, DU and BUET teachers' quarters (Dhakeswary area)

Public sector housing complexes in Dhaka city usually have better residential environment in the sense that they have relatively low density, provision of wide spacing of buildings, greenery and open spaces, wide internal drive ways etc. All of these features are present in the case study areas under this category of this research. Walk-up buildings having four, five and six floors dominate these types of housing facilities except BUET where a tower apartment of ten floors is a recent addition.

Table 2.4: Urban Texture and Ambient Environment at Survey Points of Planned Public Housing Areas

	Survey point	Open space : built-up area	Green cover : exposed hard surface	Type of case study bldg	Survey month	Immediate outdoor temp. (at the time of survey) I	Regional avg. temp * (at the time of survey), R	Temp. diff. (I- R)
Kalyanpur	K-1	6	2	Walk-up	Oct	31°c	31.4°c	-.4°c
				Walk-up	Oct			
DU	DU-1	3.8	1	Walk-up	Aug	28°c	28.7°c	-.7°c
				Walk-up	Aug			
BUET	BU-1	3	0.83	Walk-up	Oct	30°c	30.6°c	-.6°c
				Walk-up	19 Oct	30°c	31.9°c	-1.9°c
				Walk-up	19 Oct			
				with Lift	21 Oct	26°c	26.4°c	-.4°c

Note: * The regional average temperature data of the same date and time with the corresponding survey measurements is collected from *Russia's Weather Server* >> *Weather Archive* >> *Asia* >> *Bangladesh* >> *Dhaka (#41923), URL: http://meteo.infospace.ru*

Due to the presence of several public university and college campuses in proximity, the survey points of DU and BUET survey points have large areas of formally landscaped green and open spaces. While at Kalyanpur, the survey point have the lowest amount of built up area among all other surveyed areas in this research. This is because the area is surrounded by large spans of undeveloped government lands, several housing facilities allotted for government service holders and many government institution campuses. All three of the 'survey points' showed lower outdoor temperature than the Dhaka regional average temperature at the time of survey (Table 2.4).

2.3a: Case study of 'Apartment with lift' 2.3b: Case study of 'Walk-up' type building

Picture 2.3: Exterior view of surveyed buildings at 'Survey point BU-1'at BUET, Dhakeswary campus; ample open space with adequate green coverage.

2.4a: Case study of 'Walk-up' type buildings. 2.4b: Case study of 'Walk-up'buildings.

Picture 2.4: Exterior view of surveyed buildings at 'Survey Points DU-1' at Shahid Giasuddin Residential area, Dhaka University; ample open space with adequate green coverage.

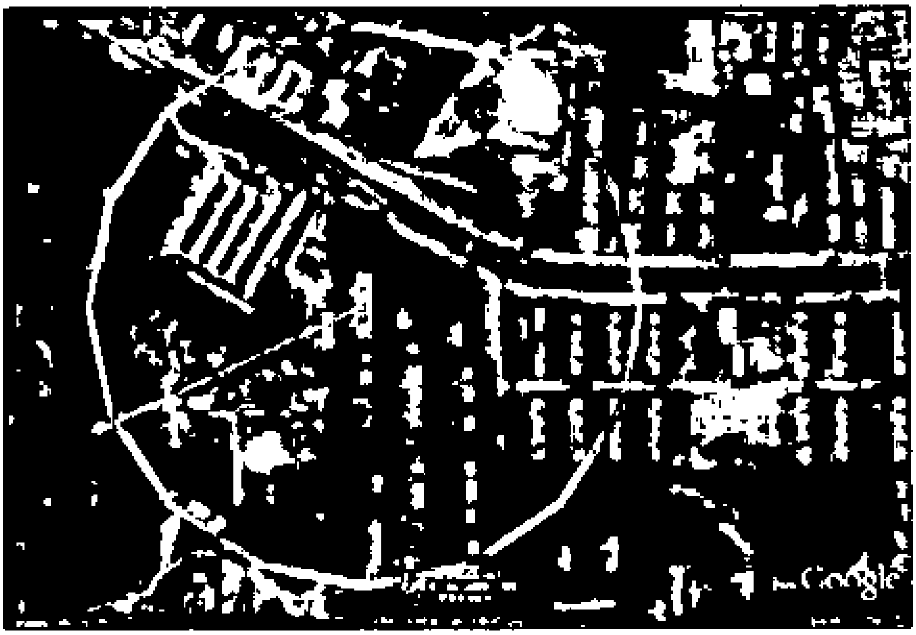


Plate 2.15: Location of 'Survey point K-1': 'Google Earth' Image

Planned public housing: Kalyanpur

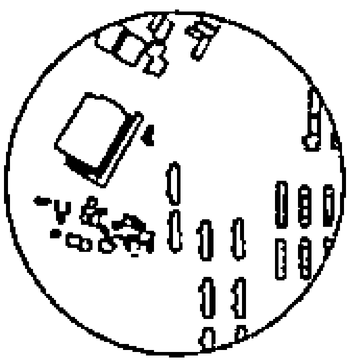


Figure 2.15a: Built-up area within K-1

Figure 2.15b: Green coverage within K-1

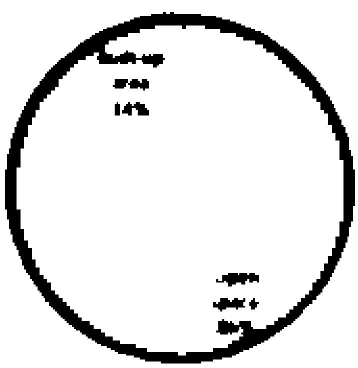


Figure 2.15c: Open space and built-up area ratio at K-1

Figure 2.15d: Green cover and exposed hard surface ratio at K-1

Plate 2.16: Location of 'Survey point BU-1'; 'Google Earth' image
Planned public housing: BUET TQ

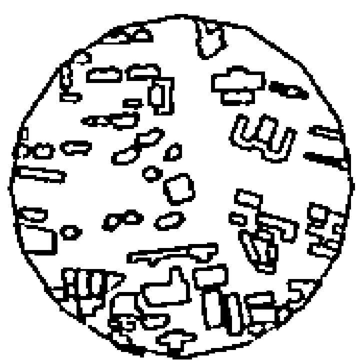


Figure 2.16a: Built-up area within BU-1

Figure 2.16b: Green coverage within BU-1

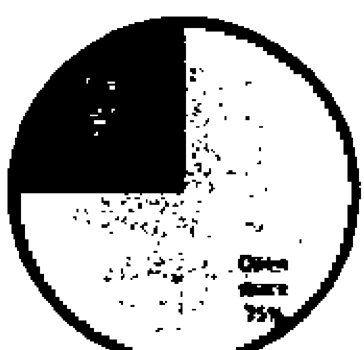


Figure 2.16c: Open space and built-up area ratio at BU-1

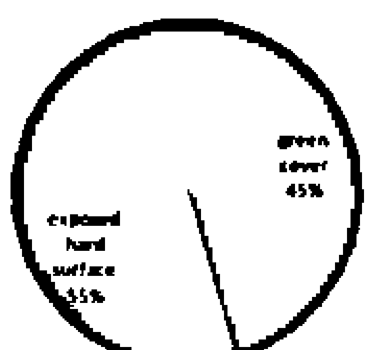


Figure 2.16d: Green cover and exposed hard surface ratio at BU-1

Plate 2.17: Location of 'Survey point DU-1': 'Google Earth' Image
Planned public housing: Shahid Giasuddin Residential area, DU

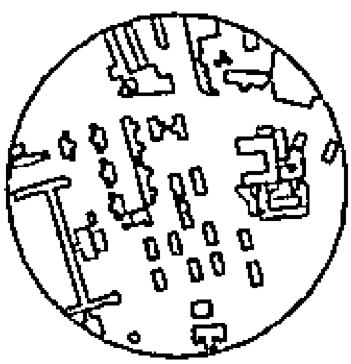


Figure 2.17a: Built-up area within DU-1

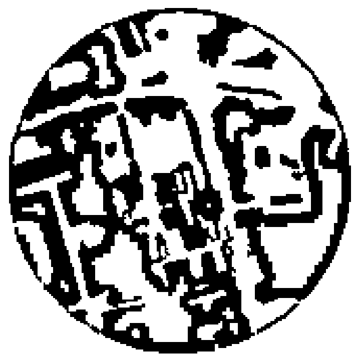


Figure 2.17b: Green coverage within DU-1

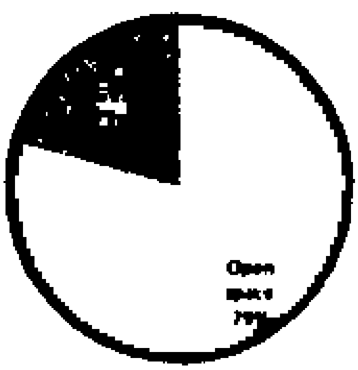


Figure 2.17c: Open space and built-up area ratio at DU-1

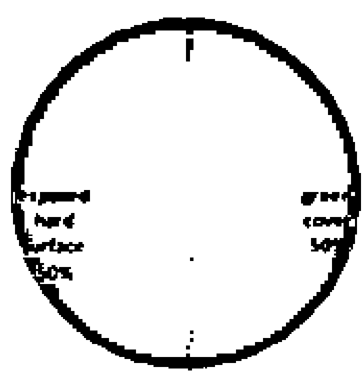


Figure 2.17d: Green cover and exposed hard surface ratio at DU-1

2.4 Form and Immediate Surroundings of the Case Study Buildings

Access to natural light, natural ventilation, amount of heat gain in a building is affected by the characteristics of the building form and the immediate surroundings. Therefore the primary physical survey of the case study buildings focused on examining certain physical characteristics related to the building itself and other buildings in the immediate surroundings. Among the 30 case study buildings, 8 study buildings are located in planned private areas, 14 study buildings are located in unplanned private settings and the rest of the 8 study buildings are located in the planned public housing complexes. The survey revealed that the physical characteristics of overall building form and surrounding spaces are different in different types of residential developments.

2.4.1 Building form

The survey shows that, the average building height is higher in unplanned private areas than the other types of developments. Moreover, the buildings within these areas differ widely in their heights. The difference of height between the lowest and highest building is 31 meters. This is mainly because, unlike the other two types of developments, no height regulation for residential buildings is followed in these areas. The average floor length and depth ratio of the buildings do not vary much in the private sector developments but the buildings in the public housing are more linear in shape with lesser depth which allows sunlight to reach core areas of the floor.

2.4.2 Building density

The unplanned private areas are also more congested because they have non-homogenous plot sizes and lack a regular road network. Road widths and turnings are often encroached by infill illegal developments (Figures 2.8a, 2.9a, 2.10a, 2.11a, 2.12a, 2.13a, 2.14a). The average distance from adjacent buildings in unplanned areas is half of that of planned private developments and one-fourth of the cases in planned public housings (Table 2.5). The ratio of distance and height of adjacent buildings is the defining factor for shadows casted on any building surface, which affects heat gain and access to sunlight for the building in question. The survey shows that, the ratio of mean distance (mD) to mean height (mH) of adjacent buildings is the lowest in unplanned private areas. In fact, the average height of the adjacent buildings from the case study buildings is more than double than the average distance in between, which means the adjacent buildings are more likely to over-shadow the case study buildings for a longer period of the day. Table 2.5 shows the survey results regarding form, shape and surroundings of the case study buildings.

Table 2.5: Form, Shape and Surrounding of the Case-Study Apartment Buildings.

	Location	Survey point	Building Type	Height of bldg.(m) h	Avg. distance of adjacent bldgs(m) mD	Avg. height of adjacent bldgs(m) mH	mD/mH	length-depth ratio of floor area l/d
Planned private developments	Uttara	U-1	Walk-up	13.4	5.2	11	0.47	1.4
		U-2	with Lift	18	8.2	10	0.82	1.5
	Mirpur	M-1	with Lift	18	12.9	8.6	1.5	1.9
			Walk-up	13.4	10	10	1	1
	Gulshan	G-1	Walk-up	10	14	17.5	0.8	1.5
		G-2	with Lift	20	17.4	11.6	1.5	1.3
	Lalmatia	L-1	Walk-up	15	6.5	12.8	0.51	1.7
			with Lift	20	8.8	9.9	0.89	1.8
	average			15.7	11.3	12.4	.9	1.5
Unplanned private developments	Rajabazar	R-1	Walk-up	15	6.2	4.6	1.35	1.3
		R-2	Walk-up	10	10	13.4	0.74	1
			with Lift	18	2.3	8	0.29	1.7
	Dhanmondi	D-1	Walk-up	18	2.9	31.5	.1	
			Walk-up	18	2.6	16	0.16	1.7
			with Lift	49	6	16	0.37	1.1
			with Lift	29	3	22	0.13	1.38
	Shegun-bagicha	SB-1	Walk-up	18	5	17.4	0.29	2.6
			Walk-up	18				
			Walk-up	18				
			with Lift	29	3.3	16.5	0.2	2.4
		SB-2	with Lift	41	12.4	14.6	0.85	1.1
	Shantinagar	S-1	Walk-up	13.4	9.7	19.7	0.49	1
		S-2	with Lift	33.5	2.6	13.3	0.19	2.3
	average			23.4	5.5	16.1	.43	1.6
Planned public housing	Kalyanpur	K-1	Walk-up	15	26	16.7	1.5	5.8
			Walk-up	15	12.8	9	1.42	5.8
	Dhaka University	DU-1	Walk-up	15				
			Walk-up	15	11	16.7	0.66	2.3
	BUET	BUET-1	Walk-up	18	17	13	1.31	5
			Walk-up	13.5	20.7	13.4	1.54	2.5
			Walk-up	13.5	20.7	13.4	1.54	2.5
			with Lift	37	42.7	13.4	3.18	1.02
	average			17.7	21.5	13.6	1.6	3.6

2.5 Profile of the Dwelling Units in the Case Study Buildings

The case study buildings consisted of total 432 households among which 112 households were surveyed. The questionnaire design was focused to gain information on the demand or use and actual consumption of electricity in the households.

Electricity consumption in a house hold depends on many physical, environmental, economic and socio-cultural and other issues related to individual human perceptions. Chapter 1 discussed some of these issues. This research focused on the final consumption of individual dwelling units and internal thermal and lighting condition of the dwelling unit. The use of 'energy saving bulb' was also enquired to gain some insight about the awareness and practice among the households about efficient energy use.

2.5.1 Socio-economic profile of the surveyed households

The surveyed households fall into the lower-high to higher income group of Dhaka city corporation area (see section 1.7.2.2). The major portion of the families living in the apartment houses consists of 2 to 7 members. More than 67% uses air-conditioners during the warmer months of the year and only half of the households use energy saving bulbs in some portions of the house. Survey results are shown in Table 2.6.

Table 2.6: Household (HH) Characteristics of Surveyed Dwelling Units

Total no. of HHs. surveyed	HH distribution by Family size (members)			HH distribution by Income level (in thousands)/month			Uses AC	Uses 'Energy saving' bulbs
	2 - 4	5 - 7	above	30 - 70	70 - 110	110-above		
112	55.8%	37.7%	6.5%	48%	31%	21%	67.5%	51%

The classification of households according to their income level in three types of residential area is shown in the table 2.7.

Table 2.7: HH Classification by Income in Surveyed Residential Areas

HH income range	Planned Private (p.pr.)	Planned Public (p.pub)	Unplanned private (unp.pr.)
30 to70 (thousand tk.)	7	14	17
70 to 110 (thousand tk.)	7	6	15
Above 110 (thousand tk.)	8	0	11
Total respondents	22	20	43

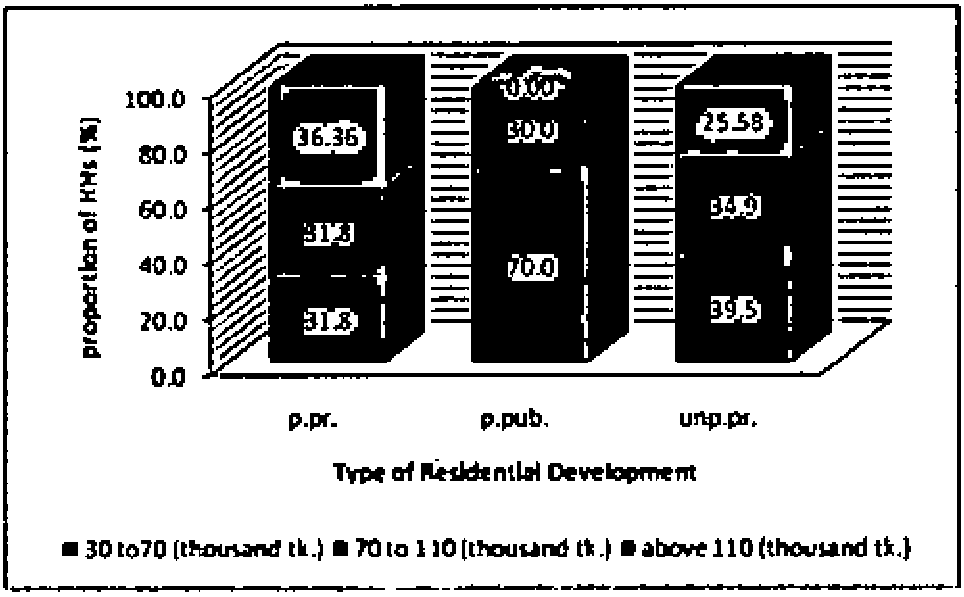


Figure 2.18: Distribution of Hhs With Different Income Level In Surveyed Residential Areas

The survey results reveal that a more all less balanced combination of all income categories is found both in planned and unplanned private developments whereas, high income households are absent in planned public housing areas. It is also evident that majority of the surveyed households living in planned public area belongs to the relatively lower income group (Figure 2.18).

2.5.2 Classification of households by electricity consumption level

The average monthly electricity consumption in individual dwelling units are calculated from averaging the amounts recorded from the copies of monthly bills for each month in a year to get a comprehensive picture by considering the seasonal variations in use. The survey shows that average monthly electricity consumption varies from as low as 119 KWh to as high as 1147KWh in the surveyed households. For ease of classification,100 to 400 KWH is ranked as 'low', 401 to 800 KWh consumption is ranked 'medium' and 801 to more is ranked as 'high' level of consumption. The survey result shows that less than 9% of surveyed households are high level consumers, more than 60% are low level consumers and the rest are moderate level consumers. The households with high consumption level are mainly found in planned private areas, although the share of all three types of households is more or less equal in these areas. The planned public housing areas can be characterized by higher proportion of households that have low consumption level (Figure 2.19).

Table 2.8: Average Household Consumption of Electricity in Surveyed Apartment Buildings by Category of Residential Developments

Category	Survey point	Bindings on electricity usage	No. of surveyed HHs	Distribution of surveyed HHs by Avg. monthly consumption level		
				Low[1]	Medium[2]	High[3]
Planned private areas	U-1	none	27	11	9	7
	U-2	none				
	M-1	none				
	G-1	none				
	G-2	none				
	L-1	none				
Unplanned private areas	R-1	none	53	33	16	4
	R-2	none				
	D-1	none				
	SB-1	none				
	SB-2	none				
	S-1	none				
	S-2	none				
Planned public areas	K-1	Inadequate system capacity for AC	32	23	9	0
	DU-1	none				
	BUET-1	limited AC use is permitted				
General(all areas)			112	60.4%	30.8%	8.8%

Note: Low[1]= 100- 400 KWh; Medium[2]= 401- 800 KWh; High[3]= 801- 1200 KWh

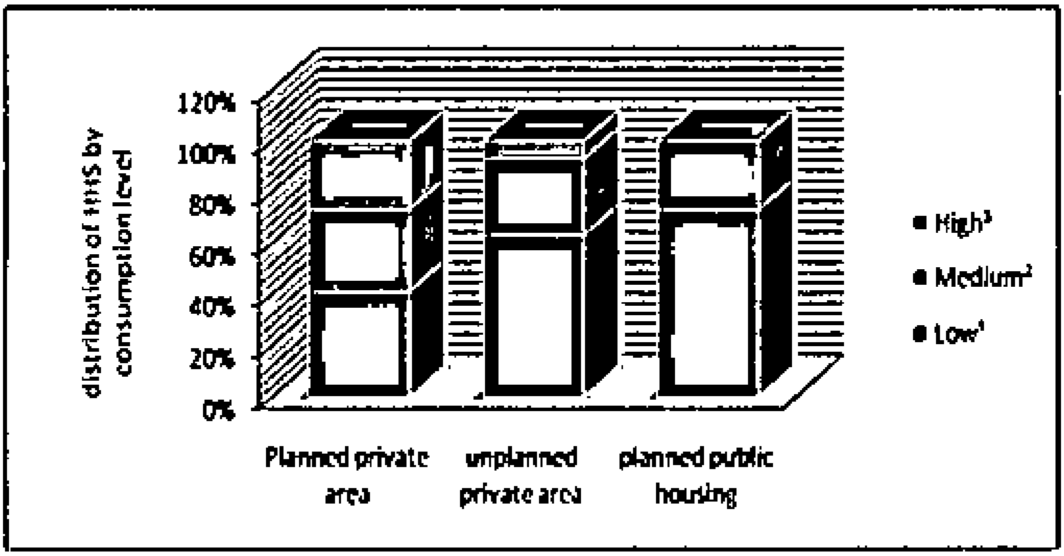


Figure 2.19: Distribution of Households by Consumption Level

2.6 Access to Natural Light and Thermal Environment in Case Study Buildings

Availability of natural light in indoor spaces and indoor temperature varies with the height of the floor in apartment buildings. To obtain the mean values, temperature and light level in indoor spaces had been measured at mid-level floors or both at higher and lower level floors to get an average picture. One objective was to find out the amount of spaces in a building which gain enough natural light for the purpose of the room according to BNBC standard (see Table 2.9) when there is enough sunlight outdoors. Another objective was to compare the indoor and outdoor thermal condition in the case study buildings. Table 2.10 shows the survey results.

On an average, 64% of the indoor spaces in the case study buildings have access to natural light as required for particular activities (Table 2.10). But the range varies from as low as 37% to as high as 90% for different cases of surveyed apartment buildings. Buildings located in planned public housing areas have the highest proportion of naturally lit indoor spaces (Figure 2.20). Figure from 2.21a to 2.21i present the building plans showing naturally lit spaces in the surveyed buildings. It is evident from the survey that due to the usual practice of compact plan layout around a common activity space usually the dining and placement of bed rooms in the outer skirts to ensure natural ventilation, the kitchen and dining areas are usually deprived of enough if not any natural light.

Table 2.9: Standard Illumination Levels for Residential Indoor Spaces

Activity area	Required LUX
Bedrooms	50
Kitchens	200
Dining rooms (tables)	100
Bathrooms	100

Source: Recommended values of illumination for residential buildings. BNBC1993

Table 2.10: Lighting and Thermal Condition in Case Study Buildings.

	Location	Survey point	Building type	Naturally lit indoor space (% of fl area)	Avg. indoor temp. I	Immediate outdoor temp. O	Diff. of temp. I-O	Survey period
Planned private developments	Uttara	U-1	Walk-up	51		29.5	-1.5	oct
		U-2	with Lift	73		27.4	.9	sep
	Mirpur	M-1	with Lift	-		-	-	-
			Walk-up	-		-	-	-
	Gulshan	G-1	Walk-up	50		23	1	nov
		G-2	with Lift	63		-	-	nov
	Lalmatia	L-1	Walk-up			-	-	-
			with Lift	76		23	1	nov
	Average			62.6				
Un-planned private developments	Rajabazar	R-1	Walk-up	78		23	0	nov
		R-2	Walk-up	38		22	0	nov
			with Lift	58		22	1	nov
	Dhanmondi	D-1	Walk-up	37		24.8	.2	nov
			Walk-up			-	-	-
			with Lift	73		29.5	.5	aug
			with Lift	61		23	-2	nov
	Shegun-bagicha	SB-1	Walk-up	50		29.5	0	sep
			Walk-up	50		29.5	0	sep
			Walk-up	50		29.5	0	sep
			with Lift					
		SB-2	with Lift	64		29.8	.7	sep
	Shantinagar	S-1	Walk-up			21	1	nov
		S-2	with Lift					
	Average			56				
Planned public housing	Kalyanpur	K-1	Walk-up	69		31	-.7	oct
			Walk-up	69				
	Dhaka University	DU-1	Walk-up	75		28	0	aug
			Walk-up	75		28	0	aug
	BUET	BUET-1	Walk-up	57		30	-1.5	oct
			Walk-up	57		30	-2	oct
			Walk-up	90				
			with Lift	55		26.5	-1	oct
	Average			63				

Data source: Survey done by the researcher during the period of August to November 2009.

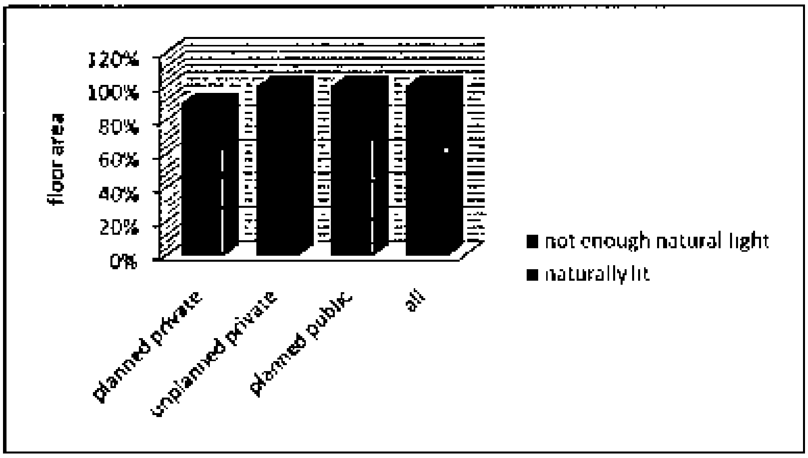


Figure 2.20: Lighting Condition in Case Study Buildings

The indoor temperature was measured at a central location usually the 'dinning space' of a dwelling unit. In warm-humid countries like Bangladesh, a cooler indoor condition is preferred for comfort, which can be achieved by use of appropriate building material for building envelop, higher wall thickness, incorporating cavity in wall sections, ample provision of shading and cross-ventilation. The survey results shown in Table 2.10 reveal that, planned public housing areas have the highest proportion of buildings with desired cooler indoor condition while in unplanned private areas they are found in negligible proportion. 75% of the buildings in the planned private areas have undesired warmer indoor condition (Figure 2.21).

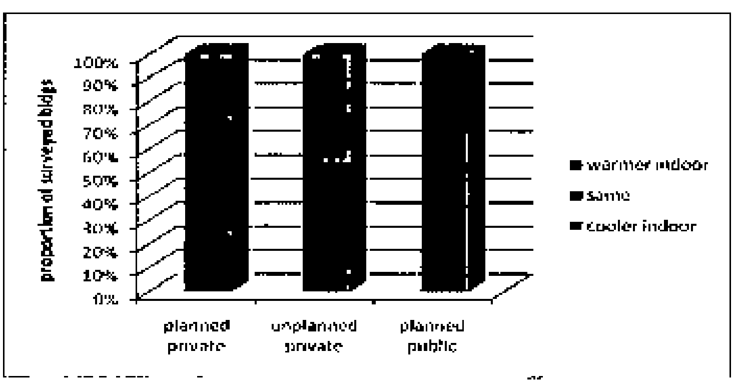
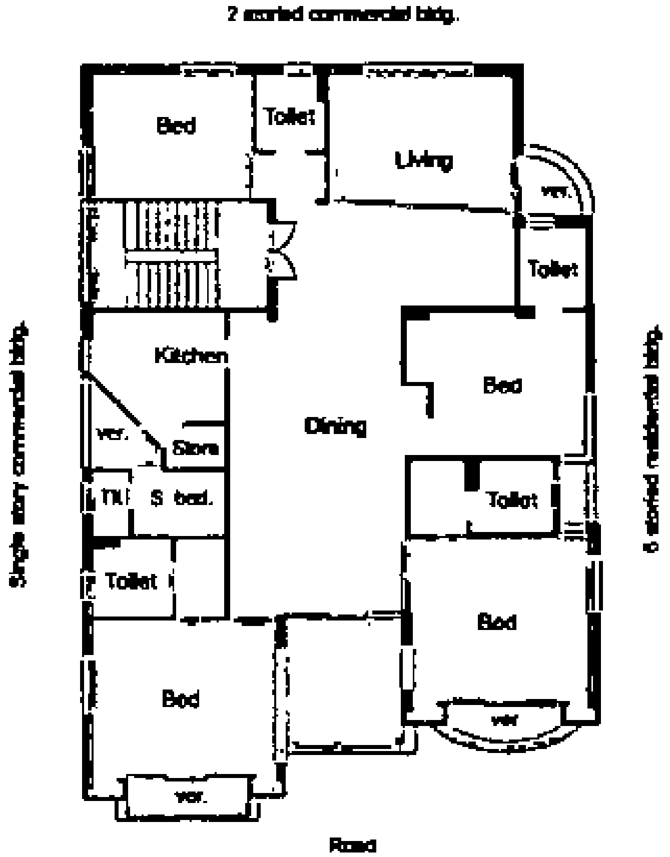
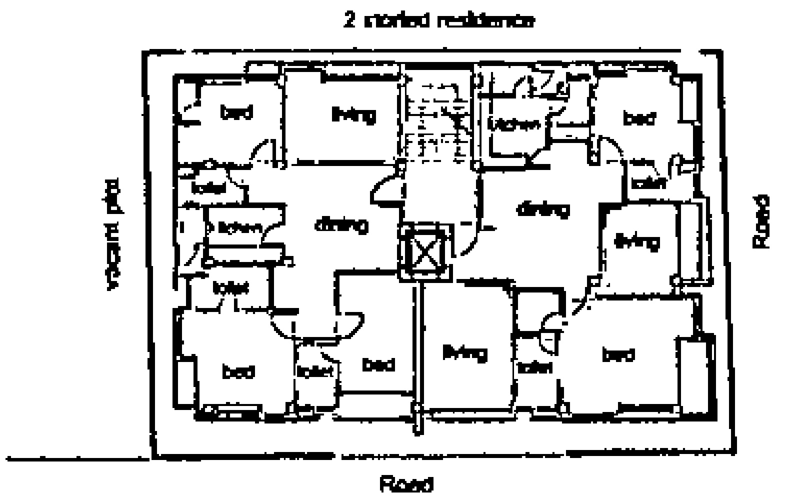


Figure 2.21: Indoor Thermal Condition in Surveyed Bldgs.

It should be noted that the study did not consider the weather variation which is evident from large variations in outdoor temperature at a same location (survey point D-1) .The readings were taken from the month of August, 2009 through November, 2009. As, the average-mean temperature in November was much lower than were in the month of August and September, the indoor air temperature acted differently in cooler seasons than in warmer ones (Table 2.10)



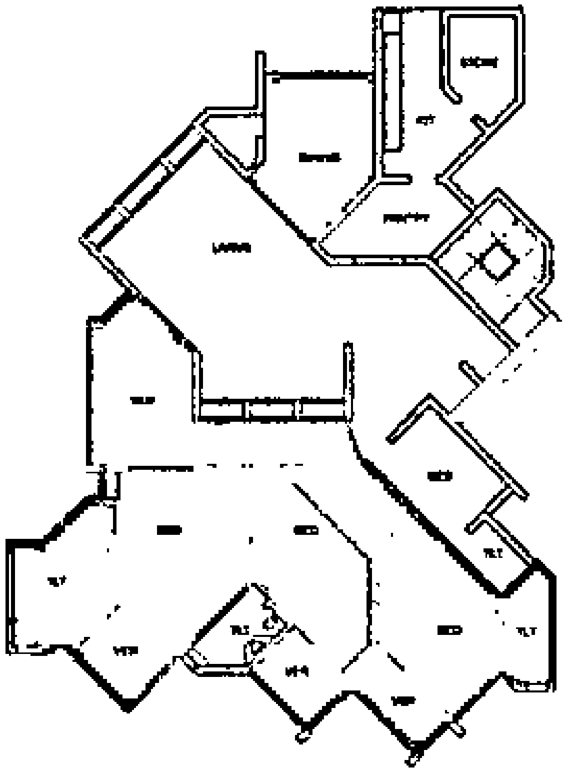
Uttara Walk- up Apartment (4 storied)
(Light level measured at 1st floor)



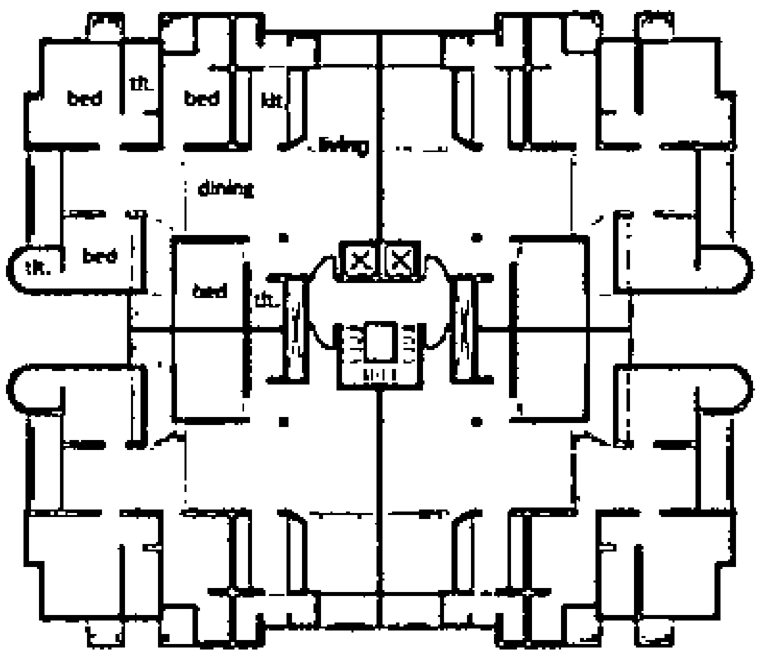
Uttara: Apartment Building (6 story)
(Light level measured on 3rd floor)

Spaces with enough natural light

Figure 2.22 a: Lighting Condition at Uttara Case Study Buildings



Gulshan Walkup-apartment building (3 story)
(Light level measured at 1st floor)
Plan layout: Not-to-scale



Gulshan apartment building with lift (6 story)
(Light level measured at 3rd floor)
Plan layout: Not-to-scale
Spaces with enough natural light

Figure 2.21 b: Lighting Condition at Gulshan Case Study Buildings

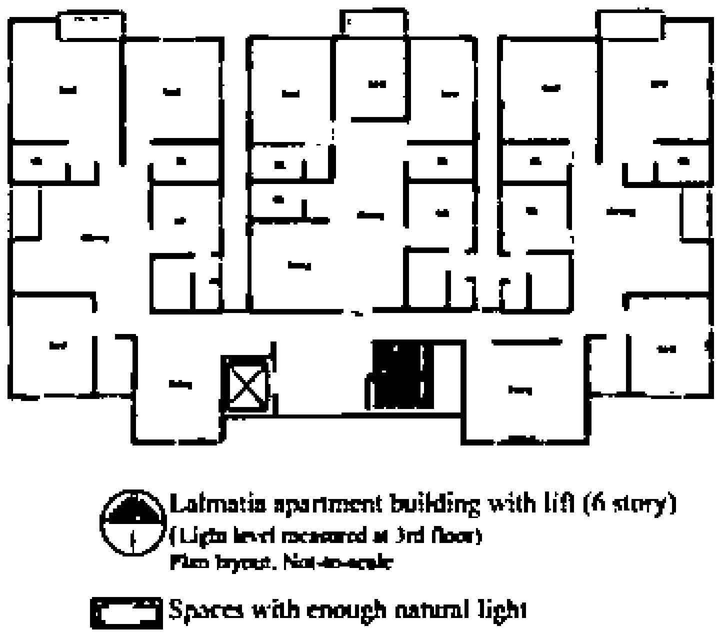


Figure 2.21 c: Lighting Condition at Lalmatia Case Study Building

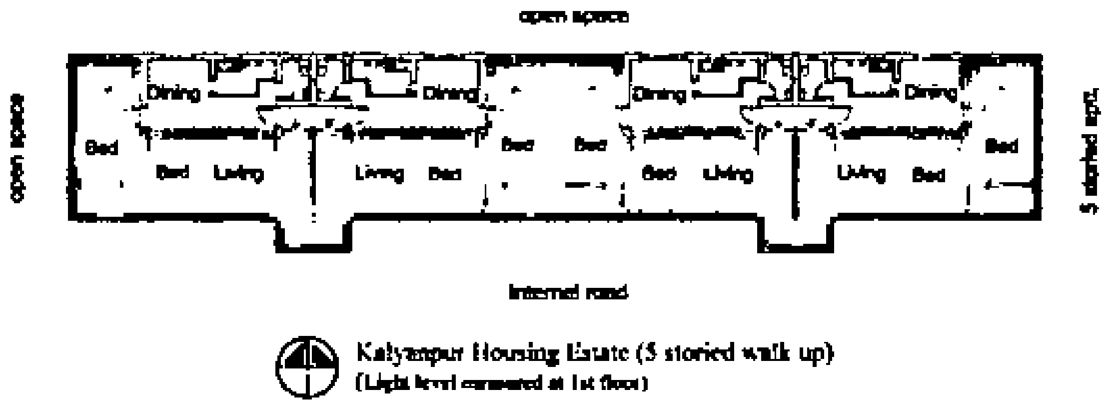


Figure 2.21 D: Lighting Condition at Kalyanpur Case Study Building

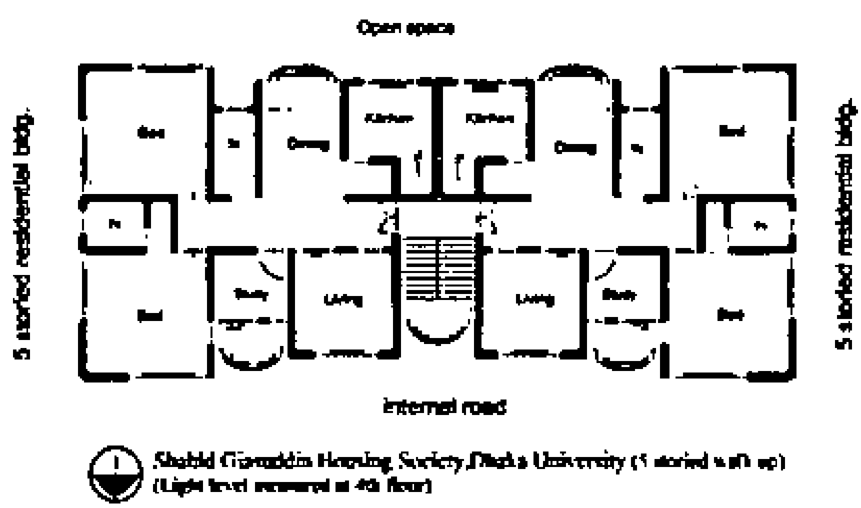
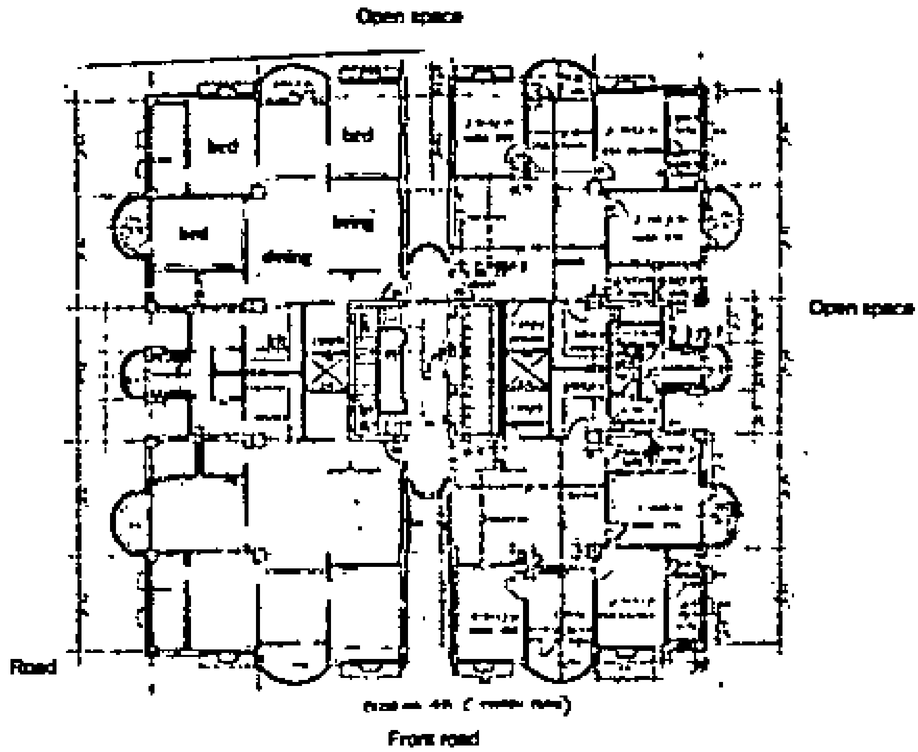
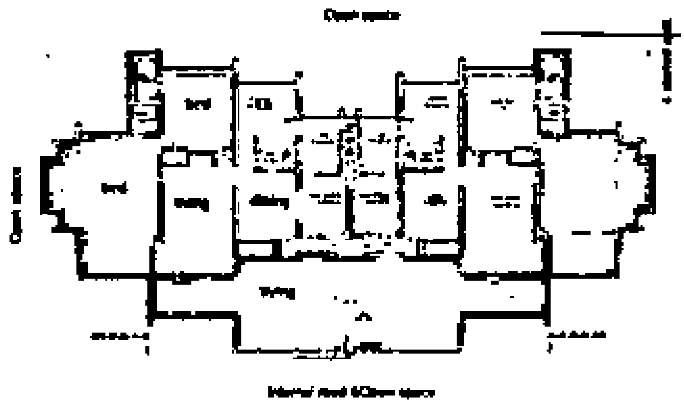


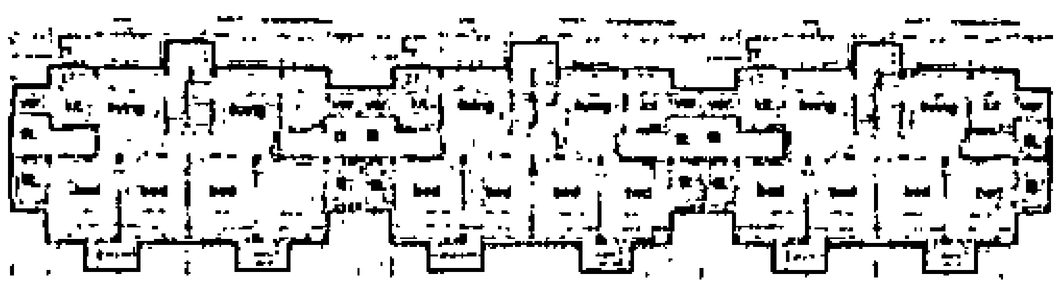
Figure 2.21 e: Lighting Condition at DU Case Study Building



Teachers quarter, Dhakeswary area, BUET (11 story)
(Light level measured at 6th & 10th floor)

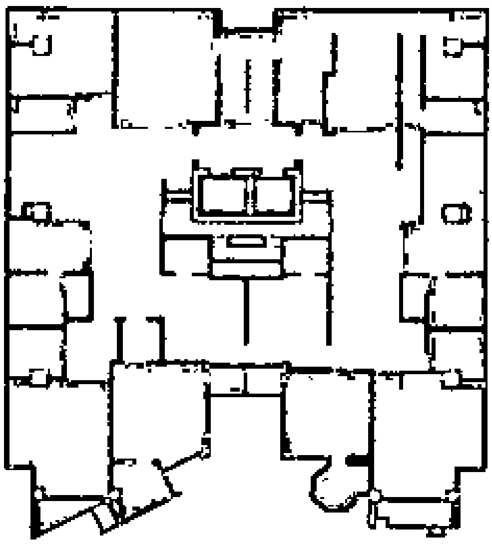


Teachers quarter, Dhakeswary area, BUET (4 storied walk-up)
(Light level measured at 2nd floor)

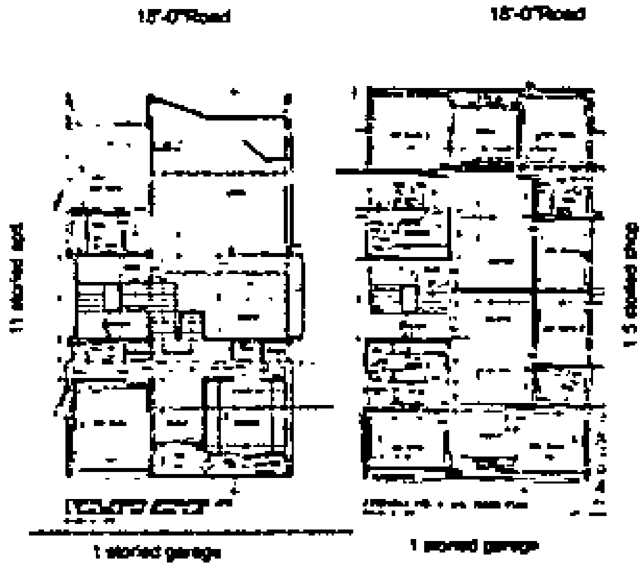


Teachers quarter, Dhakeswary area, BUET (6 storied walk-up)
(Light level measured at 3rd floor)

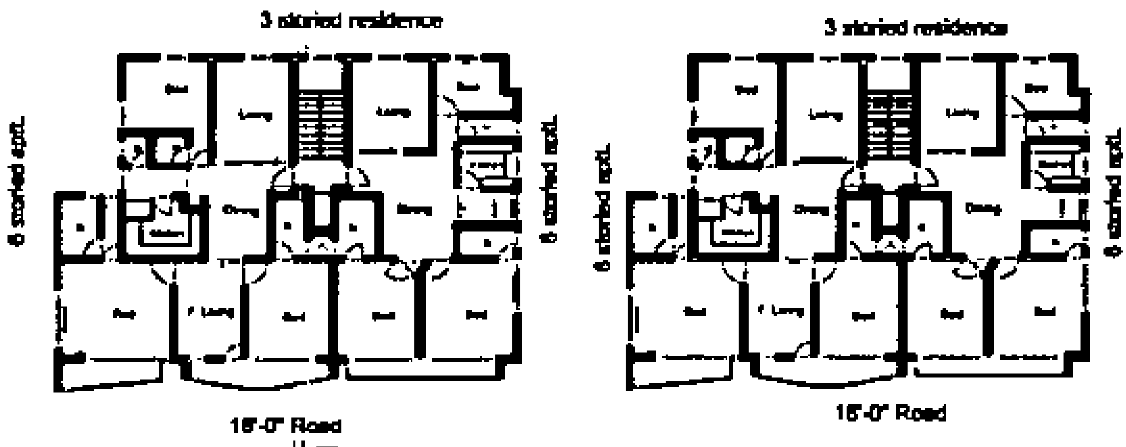
Figure 2.21 f: Lighting Condition at BUET Case Study Building



Dhanmondi: apartment building with lift (16 story)
(Light level measured at 9th floor)



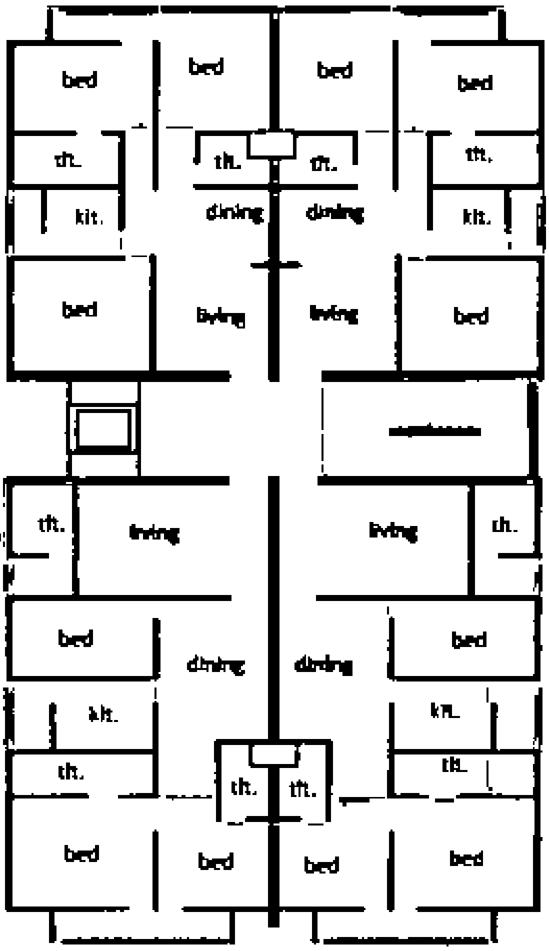
Dhanmondi Apartment (6 storied walk up)
(Light level measured at 1st & 4th floor)



Dhanmondi Apartment (9 story +basement)
(Light level measured at 3rd & 6th floor)

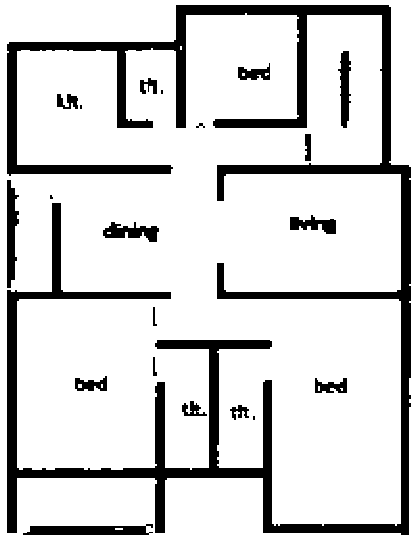
Spaces with enough natural light

Figure 2.21 g: Lighting Condition at Dhanmondi Case Study Buildings

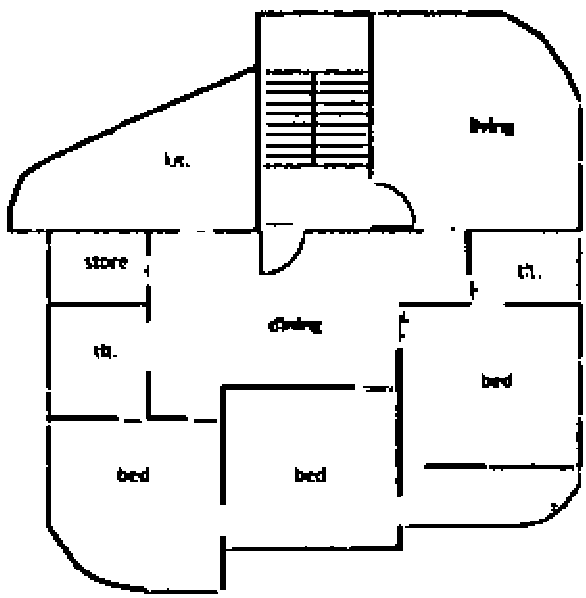


Razabazar: Apartment with lift (6 story)
(Light level measured at 3rd floor)
plan layout not-to-scale

Spaces with enough natural light

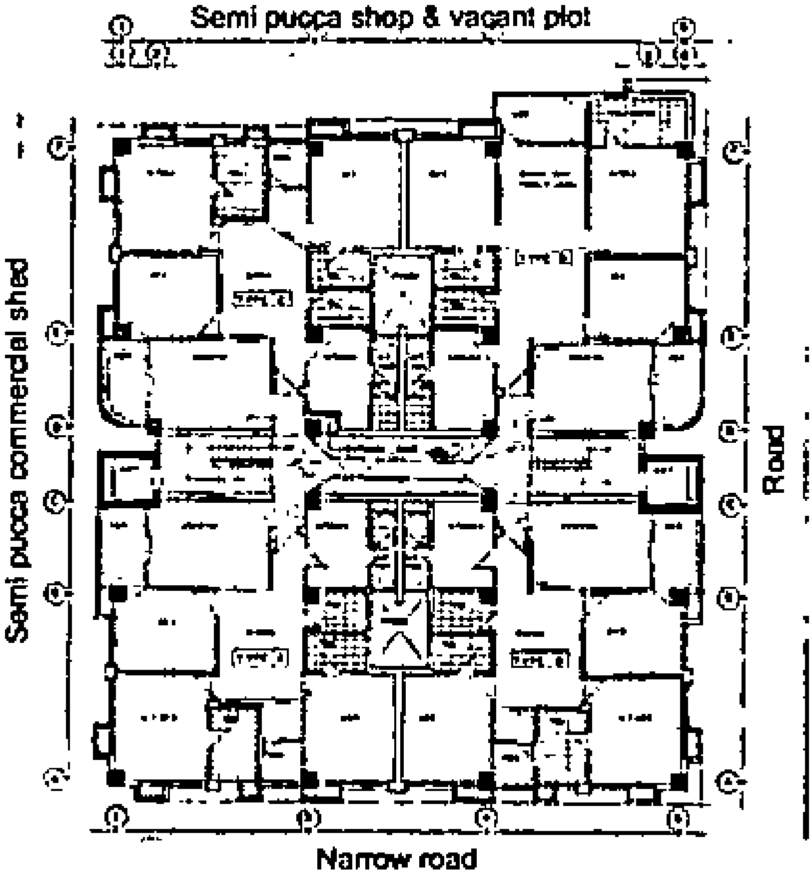


Razabazar: Walk-up apartment (3 story)
(Light level measured at 2nd floor)
plan layout not-to-scale

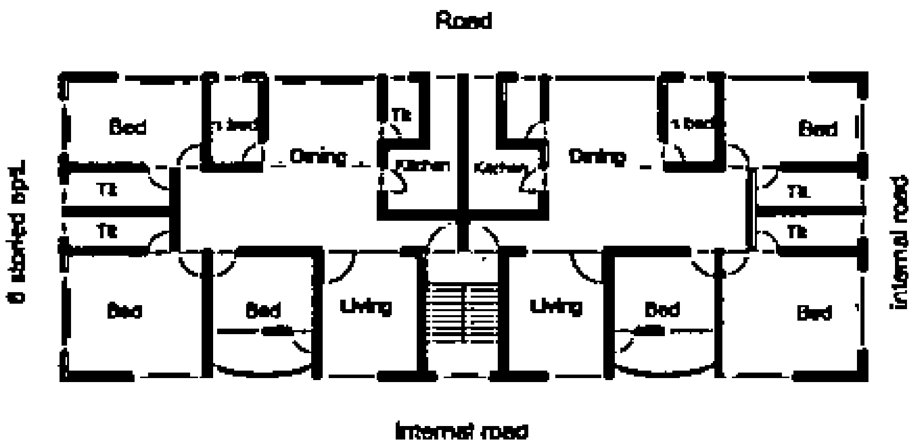


Razabazar: Walk up apartment (5 story)
(Light level measured at 2nd floor)
plan layout not-to-scale

Figure 2.21 b: Lighting Condition at Rajabazar Case Study Buildings



Shegunbagicha: Apartment Building (13 story+basement)
(Light level measured at 2nd & 10th level)



Shegunbagicha Walkup-apartment building (6 story)
(Light level measured at 1st & 3rd floor)
Plan layout: Not-to-scale
Spaces with enough natural light

Figure 2.21 I: Lighting Condition at Shegun Bagicha Case Study Buildings

2.7 Energy Efficiency of the Case Study Residential Buildings

Thirty residential apartment buildings including 19 walk-ups and 11 apartment buildings with lift facility were surveyed to find out their 'energy efficiency' in terms of electricity consumption per year per unit floor area measured in 'KWh/m²/yr.' In order to calculate the total electricity consumption of a residential building ,two main components were considered. They are:

I. The individual household consumption and
II. The consumption for building utility services like lift, water supply, lighting of common spaces etc.

The method of calculation has been described earlier in section 1.7.2.5. The 'energy efficiency' (EE) calculated for each building is given in the Table 2.11. An example of the calculations is attached in Annexure A1.

Table2.11: Estimated 'Energy Efficiency' of the Case Study Buildings

Type of dev.	Location	Survey point	Building Type	Total floor area (m²)	No. of floors	No. of dwelling unit	EE (KWh/m²/yr.)
Planned private areas	Uttara	U-1	Walk-up	929.5	4	4	35.7
		U-2	Aptt. with Lift	1729	6	10	36
	Gulshan	G-1	Walk-up	1075	3	3	38.9
		G-2	Aptt. with Lift	5354	6	20	49.8
	Mirpur	M-1	Walk-up	669	4	7	21.5
			Aptt. with Lift	2030	6	15	26
	Lalmatia	L-1	Walk-up	585	5	9	36.8
			Aptt. with Lift	2677	6	15	37.4
Unplanned private areas	Dhanmondi	D-1	Walk-up	1338.5	6	7	26.8
			Walk-up	1255	6	8	32.7
			Aptt. with Lift	7585	17	27	28.8
			Aptt. with Lift	2510	10	16	38.3
	Rajabazar	R-1	Walk-up	502	3	3	44.5
			Aptt. with Lift	2677	6	20	38.5
		R-2	Walk-up	949	5	5	28

(continued)

	Shantinagar	S-1	Walk-up	1078	4	7	26
		S-2	Aptt. with Lift	4555	10	36	38.6
	Shegunbagicha	SB-1	Walk-up	1673	6	10	31
			Walk-up	1673	6	10	30
			Walk-up	1673	6	10	32
			Aptt. with Lift	2091	10	16	32.5
		SB-2	Aptt. with Lift	8512	14	44	30
Planned public housing	Dhaka University	DU-1	Walk-up	1394	5	10	24
			Walk-up	976	5	10	25.4
	BUET	BU-1	Walk-up	1487	4	8	28
			Walk-up	1487	4	8	22
			Walk-up	5500	6	36	27
			Aptt. with Lift	13992	11	44	21
	Kalyanpur Housing Estate	K-1	Walk-up	1580	5	20	26.4
			Walk-up	1580	5	20	25

2.7.1 'Energy Efficiency' and type of residential development

The implication of the estimated 'energy efficiency' of a particular residential building is that, lower value indicates more efficient functioning compared to other similar type of buildings. The survey results show that, average consumption of electricity per unit area per year of the case study buildings is lower in planned public areas while highest in planned private areas in both types of buildings (Figure 2.22). That is, apartment buildings are more efficient in planned public housing areas and less efficient in planned private areas than in other type of settings surveyed.

As the demand for energy is directly related to the affordability of any household and therefore to the consumption level, the income level analysis in different types of residential areas described earlier in Section 2.5.1 needs to be considered here. The income level analysis showed that, the lesser consumption level in buildings of planned public areas corresponds to the fact that the higher income group is absent in these buildings. Vice-versa, the higher consumption in buildings of planned private areas can be related to the larger proportion of high income households.

Another interesting finding is that apartment buildings with lift are more efficient in planned public housing than walk-ups, while in other two types of developments walk-ups are more efficient. Although this cannot be established as a pattern as only one apartment building with lift has been surveyed that is located in a planned public housing.

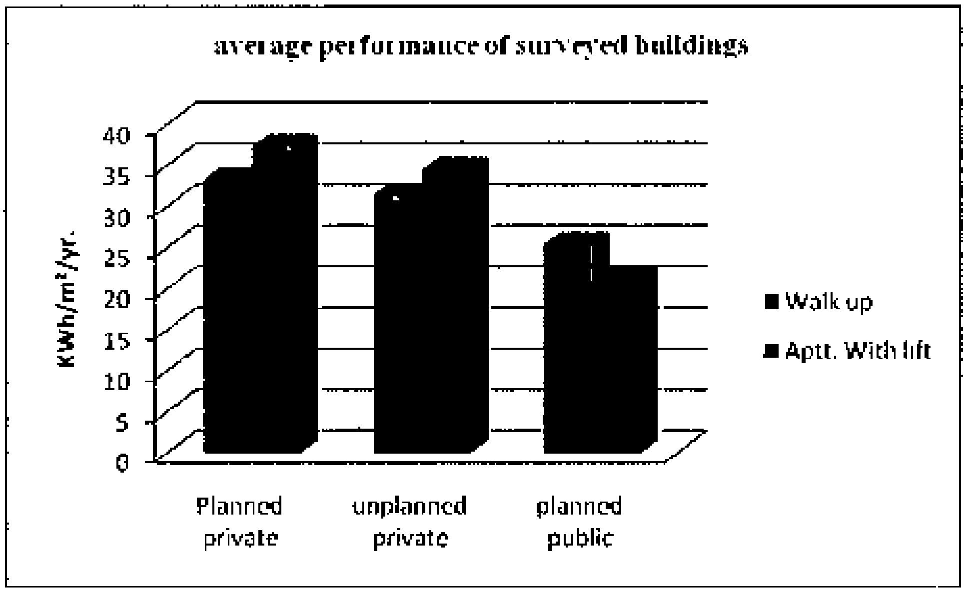


Figure 2.22: Comparison of 'Energy Efficiency' Estimates By Type of Buildings in Different Residential Developments

The estimated 'energy efficiency' ranges from as low as 21 KWh/m²/yr. to as high as 49.8 KWh/m²/yr in the surveyed residential apartment buildings. When these buildings are ranked in three separate groups, the result is a pattern similar to Figure 2.22. Figure 2.23 presents the distribution of 'more efficient', 'moderately efficient' and 'less efficient' buildings in different types of developments.

Figure 2.23 shows that all of the buildings surveyed in planned public housing category belong to the 'more efficient' group. The proportion of 'more efficient' buildings is higher in unplanned areas compared to planned private areas.

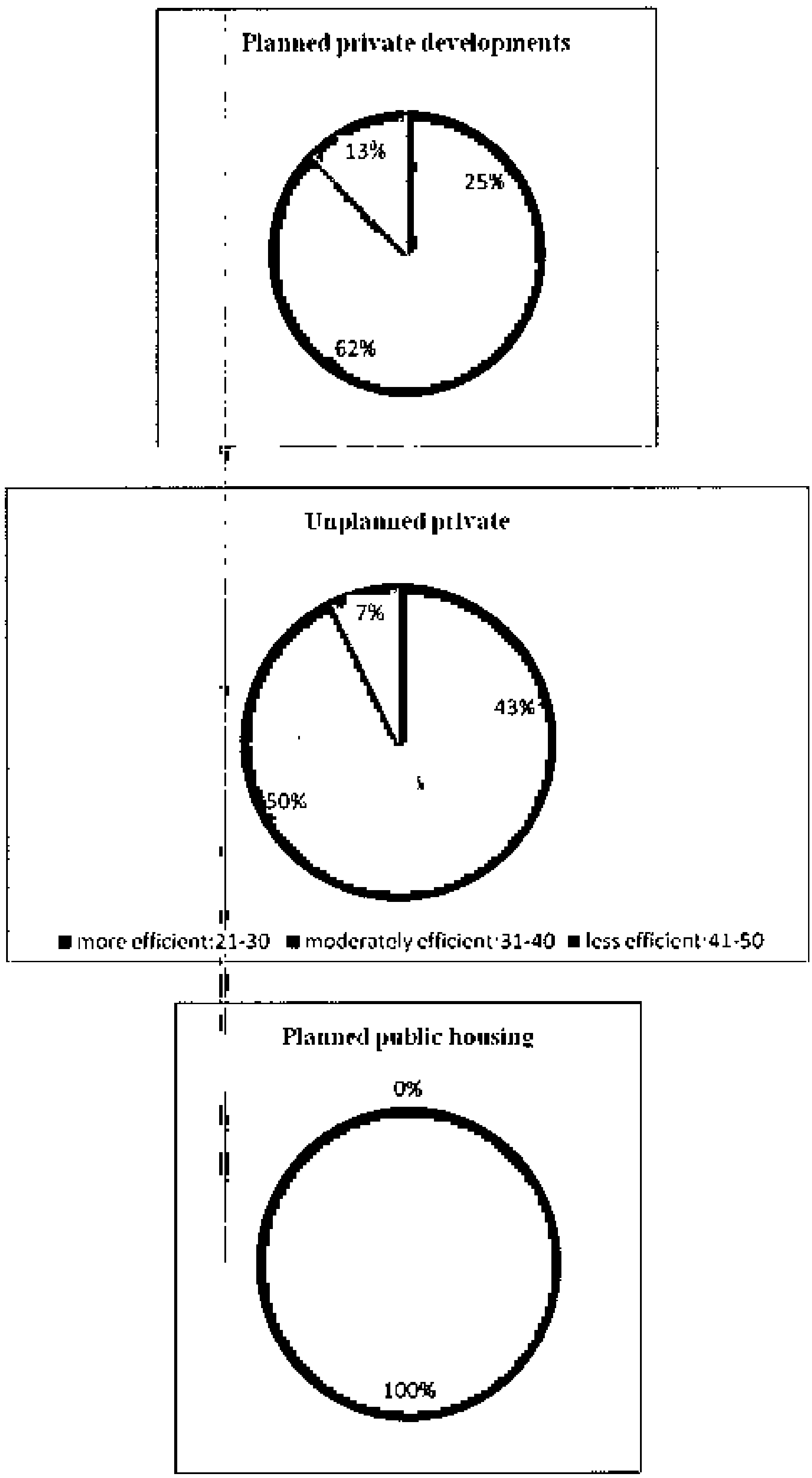


Figure 2.23: Proportion of Case Study Buildings of Different Energy Efficiency Level in Three Type of Residential Development

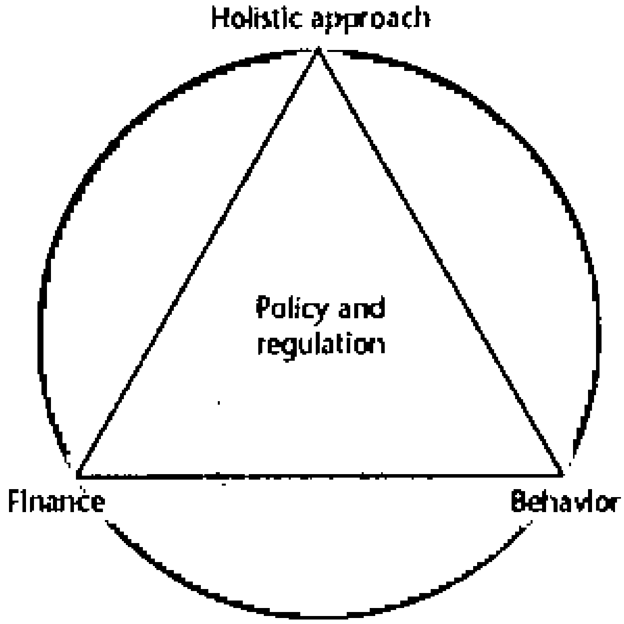


Figure 3.1: The Three Approaches in a Supportive Framework for Energy Efficiency in Buildings

Source: Summary Report, World Business Council for Sustainable Development

3.4.1 Recommendations regarding urban planning policy measures

Since policy-makers in developing countries like Bangladesh often consider energy efficiency as a low priority behind many more vital economic goals such as poverty alleviation or increased employment, it is essential that the co-benefits of energy-efficiency policies are well-mapped, quantified and well understood by the policy-makers. These co-benefits include energy security, poverty alleviation or improved social welfare, reduced mortality and morbidity or improved health, job creation and improved industrial productivity (Koeppel et al 2007).

In recent times, energy security considerations as well as rapidly rising energy demand have become a driver for energy efficiency investments and policies in Bangladesh. The government and utilities are implementing several measures like tax rebates in importing renewable energy technologies, DSM programs, such as the free distribution of CFLs etc.

Regulations for energy use, appropriate energy pricing, market demand and enabling approaches such as incentives and demonstration projects are some of the measures that need to be considered. Planning policies should also focus on:

2.7.2 Dwelling density and 'energy efficiency' of apartment buildings

The number of dwelling units varies widely in the apartment buildings of both type, i.e. in walk ups and apartments with lift. Among the surveyed buildings the number ranged from as small as 3 to as large as 44 dwelling units in a single building. To figure out if there is any impact of the number of dwelling units on the energy consumption level per unit area of a building, the surveyed cases were arranged in a hierarchical order to observe the change pattern in the corresponding 'energy efficiency(EE)'. From Figures 2.24a&b it is evident that with respect to a positively sloped trend line showing gradual increase in dwelling density the trend line for corresponding 'energy efficiency(EE)' of the buildings is negatively sloped. That is, higher dwelling density can lead to better efficiency level of a building regarding energy consumption per unit area. However, a larger sample needs to be surveyed in order to determine the optimum number of dwelling units in an apartment building.

Table 2.12: Change in 'EE' Along With Increasing Dwelling Density of Apartment Buildings with Lift

Cases (apt. with lift)	No of Dwelling units	EE of bldgs.
1	10	36
2	15	37.4
3	15	26
4	16	38.3
5	16	32.5
6	20	49.8
7	20	38.5
8	28	28.8
9	36	38.6
10	44	21
11	44	30

Data source: Survey done by researcher from August till November 2009

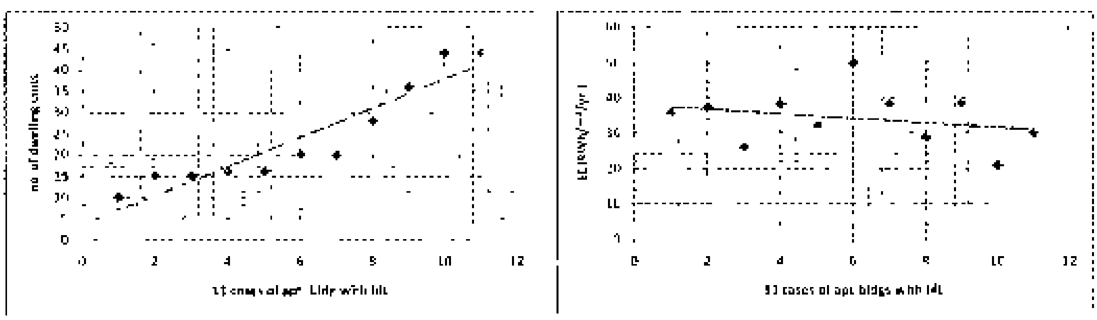


Figure 2.24a: Change in Energy Consumption Per Unit Area along with Increasing Dwelling Density: 'Apartment Building with Lift'.

Table 2.13: Change in 'EE' Along With Increasing Dwelling Density of Walk-Up Apartment Buildings

Cases (walk-up-apt)	no. of dwelling units	EE
1	3	38 9
2	3	46
3	4	35.7
4	5	28
5	7	26.8
6	7	21.5
7	7	26
8	8	22
9	8	28
10	8	32.7
11	9	36.8
12	10	24
13	10	25.4
14	10	30
15	10	31
16	10	32
17	20	25
18	20	26.4
19	36	27

Data source: Survey done by researcher from August till November 2009

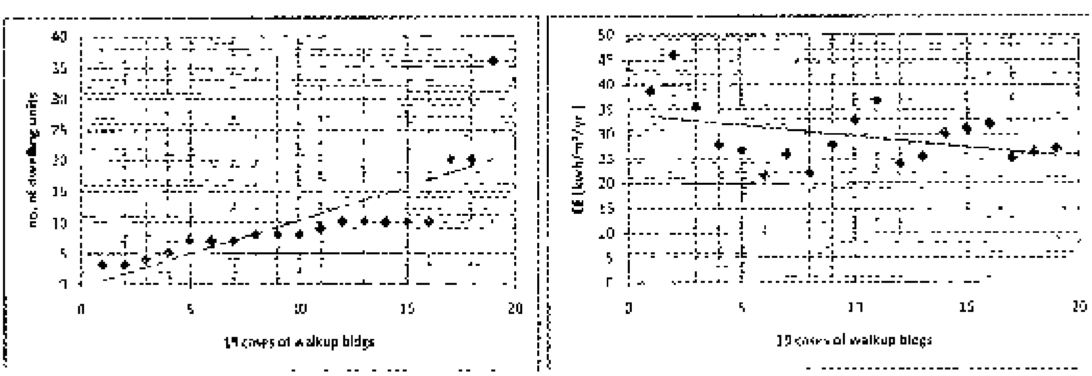


Figure 2.24b: Change in Energy Consumption Per Unit Area along with Increasing Dwelling Density: 'Walk Up Apartment Building'

2.8 Summary of Findings

The case studies discussed in the earlier sections is summarized below to get a qualitative overview of the impact of selected parameters of the corresponding urban texture and micro climate on 'energy efficiency' of the residential apartment buildings in different areas of Dhaka city . The parameters of urban texture and micro climate that were examined in the survey points are;

I. Building density: amount of open space compared to the built-up area
II. Amount of combined green cover and water bodies compared to exposed hard surface,
III Outdoor thermal condition: local air temperature compared to regional average air temperature.
IV Indoor thermal condition: indoor air temperature compared to immediate outdoor temperature.
V. Form of the building: length to depth ratio of floor plate,
VI Site surroundings: ratio of mean distance to mean height of adjacent buildings, and
VII. Amount of naturally lit indoor spaces.

The survey results of different survey points previously shown in Table 2.2, Table 2.3, Table 2.4, Table 2.5, Table 2.7. Table 2.8, Table 2.10 and Table 2.11 have been sorted and summarized to understand the relationship pattern of these parameters on energy consumption level of apartment buildings.

Table 2.14 shows the corresponding average values of the parameters for both low consuming i.e. apparently 'more efficient' and high consuming i.e apparently 'less efficient' case study buildings. It is evident from the table that better efficiency of a building corresponds to;

- larger amount of open space in the surrounding area,
- greater provision of green and water bodies,
- cooler indoor thermal conditions in warmer seasons,
- linearity of the shape of floor plate
- Higher ratio of distance to height of adjacent buildings and
- Higher access of natural light into the indoor spaces.

Table 2.14: Summery Of Findings

EE of bldg. ($KWh/m^2/yr.$)	Open space to Built up area ratio	Green / soft surface to hard surface ratio	Temp. difference Immediate outdoor - Regional avg.	Temp. difference Indoor-immediate outdoor	Length to depth ratio of floor plate	Ratio of Mean distance to mean Ht. of adjacent bldgs.	Naturally lit floor space
21-25 (more efficient)	3.3	1.1	-.6°c	-.8°c	2.5	1.6	64%
35-50 (less efficient)	1.6	.4	-.7°c	.4°c	1.6	.7	60%

2.9 Correlation Analysis

2.9.1 Correlation between affordability and energy consumption in the case study buildings

The correlation between electricity consumption per unit area in the case study buildings and the average house hold income of the corresponding survey points have been analyzed by using both Pearson correlation and Spearman's rho. The result (Table 2.15) shows that there is a significant positive correlation between affordability of the occupants and the buildings 'energy efficiency' in KWh.m²/yr. This means the higher the income level, higher is the level of consumption.

Table 2.15: Correlation Analysis; EE and Affordability

		KWh/m2/yr	avg. incm by SVpnt
KWh/m2/yr	Pearson Correlation	1	.572(**)
	Sig. (2-tailed)		.001
	N	30	30
avg. income of HHs by Survey points	Pearson Correlation	.572(**)	1
	Sig. (2-tailed)	.001	.
	N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

			KWh/m2/yr	avg. incm by SVpnt
Spearman's rho	KWh/m2/yr	Correlation Coefficient	1.000	.618(**)
		Sig. (2-tailed)	.	.000
		N	30	30
	avg. income of HHs by Survey points	Correlation Coefficient	.618(**)	1.000
		Sig. (2-tailed)	.000	.
		N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

Data source: Survey done by the researcher from August, 2009 to November, 2009
Software for correlation analysis: SPSS 12.0

2.9.2 Correlation between urban texture and energy consumption in the case study buildings

The survey results reveals that soft surface to exposed hard surface ratio of the surrounding area have significant negative correlation with the 'energy efficiency' of buildings (Table 2.16). That is, higher proportion of green cover and water bodies will lead to lower energy consumption per unit area of the buildings situated in that area.

Table 2.16: Correlation between Ratio of Soft Surface to Hard Surface in Surrounding Area and 'EE' Of Building

			KWh/m2/yr	Soft surface to exposed hard surface ratio
Spearman's rho	KWh/m2/yr	Correlation Coefficient	1.000	-.500(**)
		Sig. (2-tailed)	.	.005
		N	30	30
	Soft surface to exposed hard surface ratio	Correlation Coefficient	-.500(**)	1.000
		Sig. (2-tailed)	.005	
		N	30	30

** Correlation is significant at the 0.01 level (2-tailed).
Data source. Survey done by the researcher from August, 2009 to November, 2009
Software for correlation analysis: SPSS 12.0

The proportion of open space compared to built up area in the surrounding area and the corresponding energy efficiency of buildings also have a weak negative correlation. That is, greater proportion of open space in the surroundings may lead to lower consumption of energy in buildings of Dhaka city (see Table 2.17).

Table 2.17: Correlation between Ratio of Open Space to Built-Up Area and EE

		KWh/m2/yr	Open space to built up area ratio
KWh/m2/yr	Pearson Correlation	1	-.386(*)
	Sig. (2-tailed)	.	.035
	N	30	30
openspace to builtup area ratio	Pearson Correlation	-.386(*)	1
	Sig. (2-tailed)	.035	.
	N	30	30

* Correlation is significant at the 0.05 level (2-tailed)
Data source: Survey done by the researcher from August, 2009 to November, 2009
Software for correlation analysis: SPSS 12.0

2.9.3 Correlation between natural lighting provision and energy consumption per unit area of buildings

One of the assumptions of the study was that the provision of natural lighting in the indoor spaces will affect the energy consumption of a residential building. But no significant correlation has been found between energy efficiency of buildings and provision of natural light from the results of the survey.

2.9.4 Correlation between ambient thermal environment and energy consumption per unit area of buildings

One of the assumptions of the study was that the ambient thermal environment will affect the energy consumption of a residential building. But no significant correlation has been found between energy efficiency of buildings and provision of natural light from the results of the survey.

CHAPTER 3:

CONCLUSION AND RECOMMENDATIONS

3.1 Key Findings

In the previous chapter, the results of the survey conducted among the case study buildings to find out the existing pattern of electricity consumption in residential apartment buildings of Dhaka city expressed as their 'energy efficiency' measured in KWh/m^2/yr were presented. Estimations of 'Open Space and Built-up Area' ratio and 'Soft surface' and 'Exposed Hard Surface' ratio of the immediate surrounding area termed as 'Survey points' were presented to express the quality of 'urban texture' . Variations in indoor and outdoor temperature differences and availability of natural light in indoor spaces that were seen in cases of different urban texture were also presented. Finally, theses parameters of external and internal physical environment were correlated with the energy performance level of the case study buildings.

From the summary of findings presented in Chapter two, the following sections of this Chapter presents the key findings of the study in relation to the specific objectives of this thesis stated earlier in Section 1.3.2.

3.1.1 Existing 'energy efficiency' of residential apartment buildings in Dhaka city

Energy consumption in a building at the operation stage primarily depends on the user of the building Affordability of a user is one of the key factors which affect the user's consumption level. The present study was done on the residential apartment buildings occupied by the higher middle to higher income group of people in Dhaka city. Therefore the results do not reflect the consumption level of the whole cross section of apartment dwellers in Dhaka city. It only describes the buildings that are occupied by households who consume to ensure 'comfort' which brings forward the issue of micro-climatic and surrounding physical conditions of the buildings in question as natural factors affecting 'comfort' in indoor spaces . Although the factor of load shedding in power supply is not considered in this thesis, the findings will be useful from the point of view that seeks to improve energy efficiency level by employing passive measures to reduce demand for electricity consumption to ensure 'comfort'.

The key findings about the existing 'energy efficiency' level of apartment buildings in Dhaka city are;

I Average 'energy efficiency' of walk up apartment buildings in Dhaka City Corporation Area is 29.6 KWh/m²/yr.

II Average 'energy efficiency' of apartment buildings with lifts in Dhaka City Corporation Area is 34.3 KWh/m²/yr.

III. Walk up buildings are almost 14% more efficient than apartments with lifts.

IV. Substantial variation in 'energy efficiency' of buildings exists in different types of residential developments in Dhaka city (see Figure 2.22)

V. The buildings located in planned public housing areas consume lowest amount of energy per unit area (see Figure 2.22).

VI. If ample open space and greenery is present, such as in the case of BUET teachers' quarters, multi storied apartments can be more energy efficient than walk-ups in a similar setting (See Section 2.6.1 & Table 2.11).

VII. Highest energy consuming buildings are mostly found in planned private residential areas (see Figure 2.23)

VIII. There is a negative correlation existing between 'energy efficiency' and dwelling density of apartment buildings in Dhaka city. Higher dwelling density corresponds to lower energy consumption per unit area of a building (see Figure 2.24a and 2.24b).

IX. Household affordability has a strong positive correlation with the energy consumption per unit area of an apartment building. It can be said that people tend to consume more energy when their affordability is higher.

3.1.2 Urban texture and 'energy efficiency' of residential buildings

3.1.2.1 Open space to built-up area ratio and 'energy efficiency' of residential apartment buildings

Pearson correlation analysis done by using the survey data show that there is a significant negative correlation at .05 level, between 'open space- built up area ratio' and 'energy efficiency' of a building. This means that the higher the proportion of open space in an urban location, the lower the energy consumption in a building located there (see Table 2.14).

3.1.2.2 Green or soft surface coverage and exposed hard surface ratio and 'energy efficiency' of buildings

Pearson correlation analysis shows that there is a negative correlation significant at .05 level, between the green or soft surface to exposed hard surface ratio and 'energy efficiency' of buildings. That is, greater coverage of soft surface will lead to lower energy consumption in a building (see Table 2.13).

3.1.2.3 Energy consumption in apartment buildings and ambient thermal environment

The survey results were inconclusive in terms of establishing substantial relationship pattern between ambient thermal condition and energy efficiency of building. The probable reason for that is the small sample size taken for the survey due to time and resource limitations.

3.2 Planning implications

The third and the final objective of this research stated earlier in Chapter 1 is to evaluate the findings from the case study analyses discussed above from urban planning point of view. To achieve the goal of improved energy efficiency in the residential sector of Dhaka City, it would be useful to do the evaluation on the basis of the tools available for urban planners to influence the development process of the city.

Urban planning can intervene in the development process though three main instruments; plans, control and promotion (Adams D.1994). Development plans provide a context for control decisions by stating the strategies and principles that the planning authority will adopt in seeking to manage land use and environmental change. A development plan, like the 'Dhaka Metropolitan Development Plan (1995-2015)', indicates where the authority wishes to encourage, prevent (e.g. in case of flood planes or green belt) or direct a specific type of development. Such guidance provide a framework for the land market by helping landowners, developers and investors to know in advance what is likely to be acceptable on their own land as well as on the neighboring land.

Development control provides an administrative mechanism for the planning authority to exercise discretion on specific development proposals. The planning authority may try to control the form of a development as well as its location, specifying requirements such as access, scale, design and external appearance. One example of this type of control tool is the 'Dhaka Mahanagar Imarat Nirman Bidhimala 2008' implemented by RAJUK for Dhaka City.

Development promotion is the most active way in which urban planning interacts with the development process. Authorities seek to stimulate development and investments within their areas by promoting and marketing locations, making land available to developers and providing grants and subsidies.

Relevance of proper implementation and up-gradation of these tools with the findings of this research is discussed below;

I. Spatially un-balanced urbanization in Bangladesh has created un-sustainable built environment in the capital city. The unplanned high density built up area is creating residential environment unpleasant and dependant on energy intensive artificial solutions. Decentralization of infrastructural facility and economic activities should be the priority of regional spatial planning objectives.

II. Dhaka's housing sector is primarily dependant on the private sector. Although the research showed that public housing facilities are more energy efficient than private developments, it is unrealistic to go for all-public developments. Rather private development sector should be enabled and regulated by inducing proper policy measures to enhance their energy efficiency.

III. In the existing condition 'Walk-ups' are more efficient than high rise apartment buildings in Dhaka City. But the later type is the obvious solution for addressing land scarcity and growing housing demand. The problem should be addressed by considering the optimum number of floors for a multi-storied apartment building to achieve the 'economies of scale' and provision of open space and green space for enhanced natural lighting, ventilation and thermal comfort. United Nation Environment Programme (UNEP) advocates that, successful strategies for promoting sustainable urban development must take into account socio-economic and cultural factors. building traditions, and environmental issues. Keeping in consideration the social-cultural consequences of apartment living which is a newer concept in our social context, the scale of apartment buildings in terms of concentration of large number of households in a building should be carefully handled. Providing common spaces for interaction, proper functioning of utility services and mechanical systems are of greater importance.

IV. The research showed that higher amount of open space and greenery truly have positive effect on energy efficiency of buildings. The appropriate provision for urban open space and greenery in new residential developments. should be established by government policy and backed by proper regulations for spatial planning, so that they are considered as a design criteria from the beginning of a project. Development control measures should be used as a tool to prevent concentration of infrastructures in existing developments to discourage infill development.

V. The research showed that higher affordability leads to higher consumption. Therefore, awareness raising among the users should be a key factor so that people should be encouraged to prevent misuse of energy and also well informed to be able to conserve energy by using efficient and renewable energy technology available in the market.

3.3 Conclusion

The domestic sector is the main consumer of commercial energy in Dhaka city. It alone consumes more than 40% of the total sale of DPDC (DPDC, 2008). Therefore, energy efficiency improvements in residential buildings have large potential for energy conservation. Proper policy measures could enable the residential building sector to function more efficiently which would ultimately ensure sustainable urban environment.

The present thesis examined the electricity end-use pattern in residential apartment buildings of Dhaka City in the context of growing density and reduced scope for natural lighting and ventilation. It intended to evaluate energy performance of the buildings of this particular type against the urban textural quality that affect urban micro-climate. The assumption was that the energy efficiency of residential buildings is affected by varying provision of natural lighting, ventilation and thermal environment.

In order to fulfill the objectives of the study, case study buildings located in prominent residential areas of older and newer developments of Dhaka City Corporation area were surveyed. The study findings revealed that different types of residential developments vary in urban textural quality and there is substantial variation in 'energy efficiency' of buildings in these locations. The summary of survey findings regarding the impact of physical and environmental characteristics of immediate surroundings of a residential building shows that, energy efficiency of a residential apartment building can be positively affected by;

I. larger amount of open space in the surrounding area,
II. greater provision of green and water bodies,
III. cooler indoor thermal conditions in warmer seasons.
IV. linearity of the shape of floor plate
V. Higher ratio of distance to height of adjacent buildings and
VI. Higher access of natural light into the indoor spaces

According to the study, planned public housings consume lesser electricity per unit area than buildings located in other types of development. Although walk-ups are less electricity consuming, they are not a feasible solution to meet Dhaka's housing demand. Therefore priority should be given to proper design, construction and maintenance of multi storied housing equipped with efficient technology. Provision of urban open space and greenery is proven to be conducive to improved energy efficiency, therefore land-use planning for future residential areas in Dhaka city should conform to proper guidelines of providing these elements. Increased awareness and incentives to use efficient technology can be vital to improved energy efficiency as higher affordability and ignorance can lead to misuse of energy.

Mindless densification of dwelling structures to merely meet the demand is destroying urban space quality as well as resulting in higher dependency on fossil fuel to run artificial systems for improvement of indoor environment. As the most appropriate solution at hand, the flourishing sector of multi-storied apartment buildings demand more in depth research regarding appropriate scale, form, building material, utility and mechanical systems etc in order to make the whole system more efficient to reduce its impact on the environment. This can be achieved through proper planning and implementation of control and enabling policy measures from city planner's part.

3.4 Recommendations

Planning for sustainable urban development must be oriented towards long-term goals and utilize knowledge about the environmental consequences of different solutions. Along with a supportive policy framework, three approaches should be adopted to gain improved energy efficiency in buildings;

I. A holistic design approach,

II. Appropriate financial mechanisms and relationships among different market actors, and

III. Behavioral changes in market actors and end users.

Policies should be focused to encourage interdependence by adopting holistic. integrated approaches among the stakeholders (such as. investors. land owners, local authority, designers. suppliers, service providers, end users etc) that assure a shared responsibility and accountability toward improved energy performance in buildings and their communities. Energy should be made more valued by those involved in the development, operation and use of buildings. Policies should create enabling environment to transform behavior by educating and motivating the professionals involved in building transactions to alter their course toward improved energy efficiency in buildings.

I. Development of a strong and efficient legislative frame on the energy performance of buildings. Enactment of a proper 'building energy code'.

II. Promoting solar energy use at the household level by information dissemination about solar home systems, promotional activities highlighting savings in monitory terms etc.

III. Promoting research and development in the fields of user-friendly and cost effective renewable energy technology.

IV. Promoting adoption of 'green consumption' among urban citizens

3.4.2 Recommendations regarding urban design

I. Steps should be taken to protect urban parks and water bodies against illegal encroachment driven by immediate profit motive.

II. Urban micro climatic considerations should be given priority while designing new settlements and improving existing conditions to reduce urban heat island effect on buildings.

III. Proper implementation of existing regulatory rules for new residential developments in the private sector e.g. 'Private housing project land development rule ,2004' and 'Ponds, play ground and open space preservation rule'.

3.4.3 Recommendations regarding residential building design

Energy efficiency in buildings should begin at the neighborhood or city planning stage. A holistic approach should be adopted which will consider energy use over the whole life cycle of the building:

I. Holistic design approach should be adopted which combines different components such as space arrangement, building envelope, building material, construction management etc and technologies in the building such as HVAC, insulation, waste management, utility such as water supply, wastewater treatment etc in an integrated approach rather than focusing on individual elements.

II. The building envelope is critical to energy efficient design, which also needs to integrate shade, orientation, daylight, ventilation and appropriate materials.

III. Design should include on-site energy generation from renewable and otherwise wasted resources.

3.4.4 Recommendations for further study

The present research on the topic of energy efficiency of residential buildings in context of Dhaka city has been carried out by a single researcher in a limited scale and boundary due to time and resource constraints. Appreciating the importance of the issue, further in depth studies should be done which would contribute to develop better understanding of the impact of urban texture and micro climatic conditions on energy consumption in urban buildings. Computer aided simulations to predict indoor lighting ventilation and thermal comfort in varying urban textural condition would be very useful in this regard. Studies on the factors unique to our socio-economic and cultural context that affect the energy consumption in households are also essential to make informed choices in future urban developments.

Creating an urban built environment conducive to efficient energy use is a job that neither city planners nor the architects could accomplish on their own. City planners deal with land use at a macro level while the architects deal with site specific aspects. But there remain many in-between issues that connect these two realms when it comes to managing commercial energy demand and consumption in a holistic way by addressing its socio-cultural, economic, technical and environmental aspects which is a prerequisite for sustainable urban development. In many instances planners formulate well-intentioned land-use plans but they rarely are realized in time and then lose their contextual relevance. A development plan that would ensure livability and energy efficiency requires at the same time a holistic as well as a detailed approach to design. Unfortunately, Dhaka city still awaits that kind of a well informed, well focused and integrated plan.

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ANNEXTUREs

<u>'Energy Efficiency' Calculation</u>

Case study building: BUET Teachers' Quarter, Building No. 48, Dhakeswary area, BUET

Building type: Apartment building with lift

Number of floors: 10 + ground floor

Total floor area (1272*11) m^2

Electricity consumption at 6^{th} floor and 10^{th} floor: (source. Records from BUET Superintendant's Engineer's office)

	Monthly consumption (KWh) 2008-2009												Avg. per month	Floor Avg.s
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
6-a	291	270	349	648	653	625	444	403	437	499	294	311	435	1861
6-b	507	473	643	860	592	643	511	518	673	747	508	507	601	
6-c	436	391	414	780	450	528	693	737	739	713	372	394	554	
6-d	197	165	238	322	298	344	313	297	338	324	203	214	271	
10-a	130	121	147	177	159	220	165	169	191	208	141	139	164	1473
10-b	302	284	338	428	395	434	355	378	424	465	350	362	376	
10-c	363	308	376	478	456	439	444	444	520	417	300	372	410	
10-d	351	349	404	550	534	692	662	613	823	441	445	405	523	

Average per floor consumption of the building = (1861+ 1473)/2 = **1667** KWh/floor/month

Consumption for common utility services = 8000 KWh/ month (assumed)

Total consumption of building per year = (1667*10 + 8000) 12 = 296040 KWh/year.

Energy Efficiency of Building no. 48;

EE = 296040/ (1272*11) = **21 KWh/ m^2/ yr.**

Annexure A2

Questionnaire survey format

Electricity Consumption of a Residential Apartment Building

General Information:			
1	Name & Address*		
2	Land area		Katha/Bigha
3	Building area*		Sft.
4	Number of floors*		Nos.
5	Number of units per floor*		Nos
6	Car parking	Ground fl □ 1st basement □ 2nd basement □ other ---	
7	Total number of flats/ units in the building		Nos.
8	Community area	Ground fl □ 1st floor □ other ---------	

Service facility:				
1.	Lifts	Size:		
		Capacity:		
2.	Generator	Type:		
		Capacity:		
3.	Electricity consumed for common purposes (common-space lighting, lift, water supply etc)	*		kWh/ month avg.

Site surrounding: *			
		Land use	Height of structures
1.	East Side		
2.	West side		
3.	North side		

4.	South side		

Electricity consumption in an apartment unit-

Apartment unit: Floor*_______ Exposed sides : east☐ west☐ north☐ south☐

Inside area*			Sft.
Number of residents*			Nos
Average monthly household expenditure (please tick) *	30,000- 50,000		Tk/ month
	50,001- 70,000		
	70,001- 90,000		
	90,001- 1,10,000		
	above		

Electrical appliances	number	specification
AC*		________ tons
Fans (ceiling & other)		3 blade fan
		4 blade fan
		Exhaust fan
Tube lights		4 feet long
		2 feet long
Incandescent bulbs		________ Watt
Energy saving bulbs*		________ Watt

Monthly record of electricity consumption (last one year):

Month	Jan*	Feb*	Mar	Apr	May	Jun*	Jul*	Aug	Sep	Oct	Nov	Dec
kWh												

Physical Survey check list

Date:

Time:

Location:

Address:

Building type: Apartment building w☐lift ; Walk-up apartme☐building

Immediate- outdoor temperature at the time of survey☐DB ☐ WB

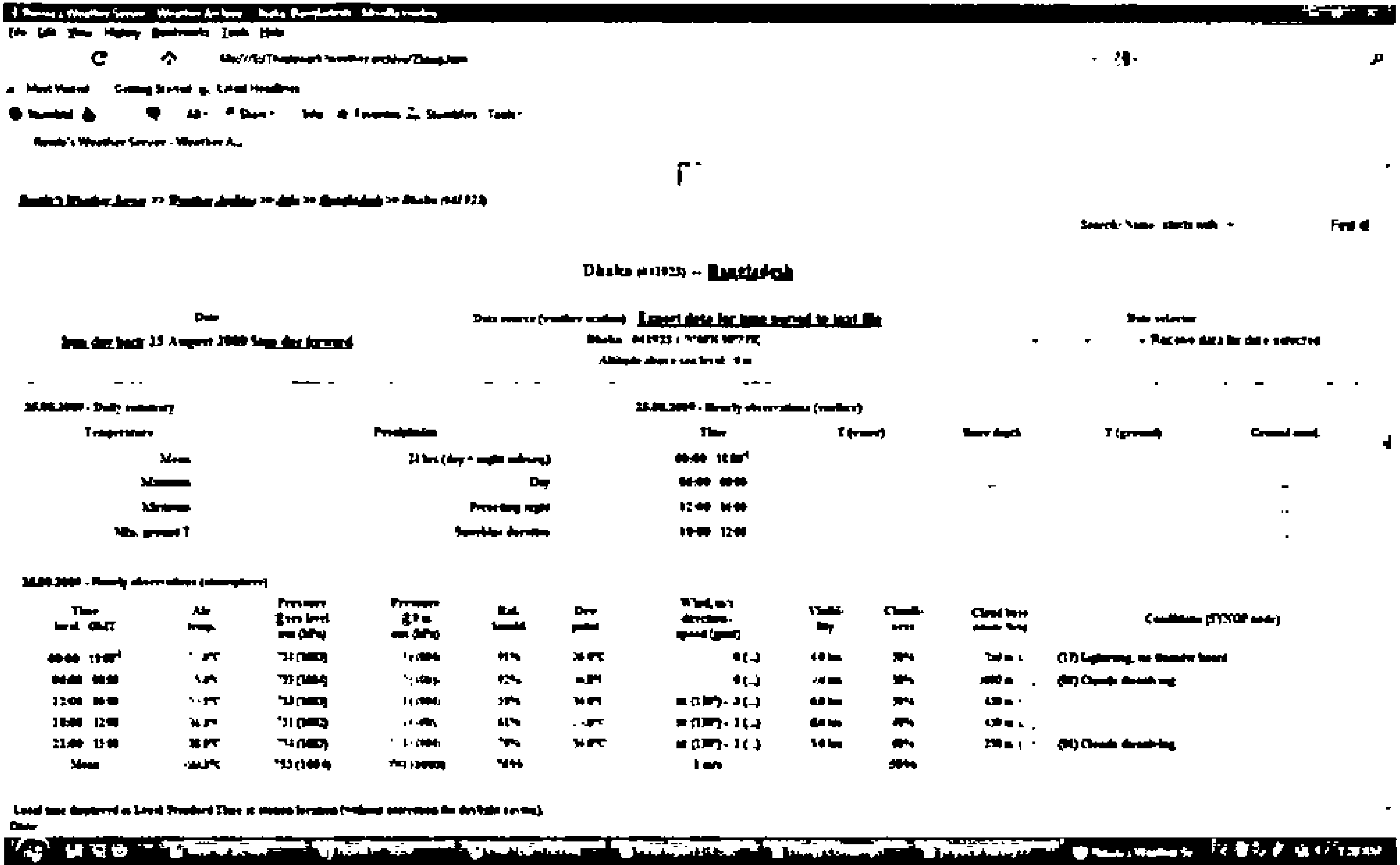
Photo graph (street front):

Internal layout:

Level/floor	Exposed sides	Indoor temperature (°C) (Central location)		Light level(lux)				
		DB	WB	Common activity area (din-cum liv)	M.bed	Kitchen	Toilets M	C

Annexure A3

Weather archive: Reference temperatures for survey dates



Dhaka (41923) -- Bangladesh

Date

One day back 15 August 2009 One day forward

Data source (weather station) Export data for time period to text file

Altitude above sea level: 8 m

Date selector

15.08.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night subseq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

15.08.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 18:00				
06:00 00:00				
12:00 06:00				
18:00 12:00				

15.08.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @ sea level (hPa)	Pressure @ ? m (hPa)	Rel. humid.	Dew point	Wind, m/s direction speed (gust)	Visibility	Cloud-iness	Cloud base	Conditions (SYNOP code)
00:00 18:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 (...)	[illegible]	[illegible]	[illegible]	(17) Lightning, no thunder heard
06:00 00:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 (...)	[illegible]	[illegible]	[illegible]	(03) Clouds developing
12:00 06:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
18:00 12:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
21:00 15:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(03) Clouds developing
Mean	[illegible]	[illegible]	[illegible]	[illegible]		1 m/s		[illegible]		

Local time displayed is Local Standard Time at station location (without correction for daylight saving).

Dhaka (41923) - Bangladesh

Date

[illegible] 26 August 2009 [illegible]

Data source (weather station): Export data for time period to text file

Dhaka 41923 [illegible]

Altitude above sea level: 9 m

Date selector

[illegible]

26.08.2009 - Daily summary

Temperature		Precipitation	
Mean	[illegible]	24 hrs (day + night [illegible])	[illegible]
Maximum	[illegible]	Day	[illegible]
Minimum	[illegible]	Preceding night	[illegible]
Min. ground T	[illegible]	Sunshine duration	[illegible]

26.08.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground state
06:00 00:00				
12:00 06:00				
18:00 12:00				

26.08.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure (sea level) (hPa)	Pressure (station) (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloud-iness	Cloud base	Conditions (SYNOP code)
06:00 00:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12:00 06:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
18:00 12:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rain [illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]		2 m/s		[illegible]		

Local time displayed is Local Standard Time at station location (without correction for daylight saving)
GMT to Local Standard time conversion used for station Dhaka (#41923): Local Standard time = GMT+6:00

Done

Dhaka (41923) – Bangladesh

Date: Step day back 11 September 2009 Step day forward

Data source (number station): Export data for time period to text file

Dhaka #41923 (23°46'N 90°23'E)

Altitude above sea level: 8 m

Date selected: Recover data for date selected

11.09.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night midway)	
Maximum	–	Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

11.09.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 / 18:00[1]		–		–
06:00 / 00:00	–	–	–	–
12:00 / 06:00	–	–		–
18:00 / 12:00		–		–

11.09.2009 - Hourly observations (atmosphere)

Time local / GMT	Air temp.	Pressure @ sea level mm (hPa)	Pressure @ 9 m mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction, speed (gust)	Visibility	Cloudiness	Cloud base above land	Conditions (SYNOP code)
00:00 / 18:00[1]	+28.7°C	753 ([illegible])	754 ([illegible])	90%	+26.8°C	0 (–)	3.0 km	80%	250 m ( )	
06:00 / 00:00	+28.0°C	753 ([illegible])	754 ([illegible])	87%	+26.0°C	0 (–)	3.0 km	80%	250 m ( )	
12:00 / 06:00	+30.0°C	753 ([illegible])	754 ([illegible])	84%	+27.0°C	[illegible] ([illegible]) 3 (–)	7.0 km	90%	250 m ( )	(21) Rain (past hour)
18:00 / 12:00	+29.0°C	753 ([illegible])	753 ([illegible])	87%	+27.0°C	0 (–)	6.0 km	40%	450 m ( )	(01) Clouds dissolving
Mean	+28.8°C	753 ([illegible])	754 ([illegible])	90%		0 m/s		70%		

Local time employed is Local Standard Time at station location (without correction for daylight saving).

GMT to Local Standard time conversion used for station Dhaka (41923): Local Standard time = GMT + 6:00.

Dhaka (41923) -- Bangladesh

Date: Step day back 12 September 2009 Step day forward

Data source (weather station): Export data for time period to text file

Dhaka 41923 [illegible]

Altitude above sea level: 9 m

Date selector: Receive data for date selected

12.09.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night sub-seq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

12.09.2009 - Hourly observations (surface)

Time		T (water)	Snow depth	T (ground)	Ground cond.
00:00	18:00[1]				
06:00	00:00				
12:00	06:00				
18:00	12:00				

12.09.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure (sea level) (hPa)	Pressure (station) (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base	Conditions (SYNOP code)
00:00 - 18:00[1]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 (...)	4.0 km	--	[illegible]	
06:00 - 00:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 (...)	4.0 km		[illegible]	(05) Haze
12:00 - 06:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 (...)	6.0 km	30%	[illegible]	
18:00 - 12:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 (...)	4.0 km	10%	[illegible]	
Mean	[illegible]	[illegible]	[illegible]	[illegible]		0 m/s		--		

Local time displayed as Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion used for the station Dhaka (41923): Local Standard time = GMT +6:00.

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Search: Name starts with Find it

Dhaka (41923) -- Bangladesh

Date

Step day back 13 September 2009 Step day forward

Data source (weather station) Export data for time period to text file

Dhaka 41923 (23°46'N 90°23'E)

Altitude above sea level: 9 m

Data selector

Receive data for date selected

13.09.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night volume)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

13.09.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 18:00[1]		–		–
06:00 00:00		–		–
12:00 06:00		–		–
18:00 12:00		–		–

13.09.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure (sea level) mm (hPa)	Pressure (station) mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction + speed (gust)	Visibility	Cloudiness	Cloud base (lower tiers)	Conditions (SYNOP code)
00:00 18:00[1]	+29.2°C	755 (1007)	754 (1006)	87%	+26.6°C	0 (–)	4.0 km	–	3000 m ( )	
06:00 00:00	+[illegible]°C	754 (1008)	754 (1005)	81%	+26.5°C	0 (–)	3.0 km	40%	450 m ( )	
12:00 06:00	+31.7°C	755 (1007)	754 (1006)	75%	+24.0°C	0 (–)	6.0 km	50%	450 m ( )	
18:00 12:00	+31.9°C	755 (1008)	753 (1007)	78%	+26.4°C	w (270°) + 1 ( )	6.0 km	30%	450 m ( )	
Mean	+30.0°C	754 (1008)	754 (1006)	75%		0 m/s		40%		

Local time displayed in Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion used for station Dhaka (41923): Local Standard time = GMT+6:00.

Done

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Dhaka (41923) – Bangladesh

Date: Step day back 15 September 2009 Step day forward

Data source (weather station): Export data for time period to text file

Dhaka 41923 (23°46'N 90°23'E)

Altitude above sea level: 9 m

Date selector – Display data for date selected

15.09.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night sub-sq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

15.09.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 - 18:00[1]		–		–
12:00 06:00		–		–
18:00 12:00		–		–
—		–		–

15.09.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @sea level mm (hPa)	Pressure @9 m stat (hPa)	Rel. humid.	Dew point	Wind, m/s direction, speed (gust)	Visibility	Cloudiness	Cloud base above (low)	Conditions (SYNOP code)
00:00 18:00[1]	+27.0°C	754 (1005)	[illegible]	81%	+24.0°C	[illegible] - 2 (–)	4.0 km	60%	3000 m ( )	
12:00 06:00	+31.0°C	754 (1005)	[illegible]	97%	+25.0°C	[illegible] - 4 (–)	4.0 km	90%	2.4 m ( )	(95) Thunderstorm with rain and/or snow
18:00 12:00	+28.0°C	753 (1005)	[illegible]	79%	+24.0°C	0 (–)	5.0 km	30%	450 m ( )	(01) Clouds dissolving
Mean	+27.9°C	753 (1004)	752 (1003)	89%		2 m/s		60%		

Local time displayed in Local Standard Time at station location (without correction for day light saving).

GMT to Local Standard time conversion used for station Dhaka (41923): Local Standard time = GMT+6:00

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Dhaka (41923) -- Bangladesh

Date	Data source (weather station) Export data for time period to text file	Date selector
Step day back 9 October 2009 Step day forward	Dhaka 41923 ([illegible])	Receive data for date selected
	Altitude above sea level 9 m	

9.10.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night values)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

9.10.2009 - Hourly observations (surface)

Time	T (snow)	Snow depth	T (ground)	Ground cond.
00:00 - 18:00[1]		–		–
06:00 - 00:00		–		–
12:00 - 06:00		–		–
18:00 - 12:00		–		–

9.10.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure (sea level mm (hPa))	Pressure (2.9 m mm (hPa))	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloud-cover	Cloud base (base 3ed)	Conditions (SYNOP code)
00:00 - 18:00[1]	+26.0°C	752 (1003)	[illegible]	97%	+26.0°C	0 ( )	4.0 km	90%	270 m ( )	(03) Clouds developing
06:00 - 00:00	+26.7°C	752 (1003)	[illegible]	93%	+25.0°C	0 ( )	5.0 km	90%	270 m ( )	
12:00 - 06:00	+31.0°C	754 (1002)	[illegible]	82%	+28.0°C	0 ( )	6.0 km	50%	450 m ( )	
18:00 - 12:00	+30.0°C	752 (1003)	[illegible]	75%	+25.0°C	0 ( )	5.5 km	60%	450 m ( )	
Mean	+28.7°C	752 (1004)	752 (1003)	85%		0 m/s		70%		

Local time displayed in Local Standard Time at station location (without conversion for daylight saving).
GMT to Local Standard time conversion used for station Dhaka (41923): Local Standard time = GMT+6:00

Done

Rusnak's Weather Server - Weather Archive - Dhaka, Bangladesh - Mozilla Firefox

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Dhaka (41923) -- Bangladesh

Date: Step day back 19 October 2009 Step day forward

Data source (weather station): Export data for time period to text file

Dhaka 41923 (23°46'N 90°23'E)

Altitude above sea level: 9 m

Date selector - Retrieve data for date selected

19.10.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night sum)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

19.10.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 18:00[1]		–		–
06:00 00:00		–		–
12:00 06:00		–		–
18:00 12:00				–

19.10.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @ sea level mm (hPa)	Pressure @ 9 m mm (hPa)	Rel. humid.	Dew point	Wind m/s direction - speed (gust)	Visib. lity	Cloud- iness	Cloud base above (avg)	Conditions (SYNOP code)
00:00 18:00[1]	+26 °C	756 (1008)	755 (1007)	90%	+21.0°C	0 (–)	2.0 km	40%	[illegible] m ( )	
06:00 00:00	+27 °C	756 (1008)	755 (1007)	82%	+22.0°C	0 (–)	3.0 km	–	[illegible] m ( )	
12:00 06:00	+31 °C	757 (1009)	756 (1008)	38%	+15.0°C	W (270°) - 1 (–)	6.0 km	–	3000 m ( )	
18:00 12:00	+30 °C	755 (1007)	754 (1006)	44%	+16.0°C	0 (–)	3.0 km	–	3000 m ( )	
Mean	+28.5°C	756 (1008)	755 (1007)	61%		0 m/s		–		

Local time displayed in Local Standard Time at current location (without correction for daylight saving).

GMT to Local Standard time correction used for station Dhaka (41923): Local Standard time = GMT +6:00

Done

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Russia's Weather Server >> Weather Archive >> Asia >> Bangladesh >> Dhaka (#41923)

Search: Name starts with Find it!

Dhaka (#41923) -- Bangladesh

Date	Data source (weather station) Export data for time period to text file	Date selector
Step day back 21 October 2009 Step day forward	Dhaka #41923 [illegible] Altitude above sea level, [illegible]	Receive data for date selected

21.10.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night subseq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

21.10.2009 Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 18:00[1]				-
06:00 00:00		-		-
12:00 06:00		-		-
18:00 12:00				

21.10.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @sea level mm (hPa)	Pressure @9 m mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base	Conditions (SYNOP code)
00:00 18:00[1]	[illegible]	758 (1010)	[illegible]	85%	21 [illegible]	0 (-)	4.0 km		[illegible]	
06:00 00:00	[illegible]	758 (1010)	[illegible]	89%	[illegible]	0 ( )	[illegible]		[illegible]	(05) Haze
12:00 06:00	[illegible]	758 (1011)	[illegible]	40%	+16 [illegible]	0 (-)	[illegible]	40%	[illegible]	
18:00 12:00	[illegible]	756 (1008)	[illegible]	51%	[illegible]	0 (-)	[illegible]	-	[illegible]	
Mean	26.1 [illegible]	757 (1010)	757 (1009)	66%		0 m/s		-		

Local time displayed is Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion used for station Dhaka (#41923): Local Standard time = GMT+6:00

Done

Weather Archive | Nokia PC Suite | One Touch Access | Final report | [illegible] | physical survey of | Russia's Weather Se | [illegible] AM

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Dhaka (041923) -- Bangladesh

Date	Data source (weather station) Export data for time period to text file	Date selector
Step day back 22 October 2009 Step day forward	Dhaka - 041923 (TP 0N 90°TR) Altitude above sea level: 8 m	Receive data for date selected

22.10.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night values)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

22.10.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 18:00[1]		–		.
06:00 00:00		–		.
12:00 06:00		–		.
18:00 12:00		–		..

22.10.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @ sea level mm (hPa)	Pressure @ 0 m mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base height 2nd	Conditions (SYNOP code)
00:00 18:00[1]	+23.2°C	751 (1013)	[illegible]	73%	+20.0°C	0 (..)	3.0 km	–	3000 m ( )	
06:00 00:00	+21.5°C	751 (1013)	[illegible]	91%	[illegible]	0 (..)	4.0 km	..	3000 m ( )	(05) Haze
12:00 06:00	+30.2°C	759 (1012)	[illegible]	42%	+16.0°C	0 (..)	6.0 km	..	3000 m ( )	(05) Haze
18:00 12:00	+27.9°C	754 (1009)	[illegible]	59%	+16.0°C	0 (..)	6.0 km	.	3000 m ( )	
Mean	+26.0°C	752 (1010)	757 (1009)	64%		0 m/s		–		

Local time displayed in Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion as set for station Dhaka (UTC+6). Local Standard time = GMT+6:00.

Done

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Weather Server - Weather Archive

[illegible] Weather Server >> Weather Archive >> Asia >> Bangladesh >> Dhaka (41923)

Search: Name starts with Find it

Dhaka (41923) -- Bangladesh

Date

Step day back 4 November 2009 Step day forward

Data source (weather station): Export data for time period to text file

Dhaka 41923 [illegible]

Altitude above sea level: [illegible] m

Date selector

Recent data for date selected

4.11.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night values)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

4.11.2009 - Hourly observations (surface)

Time	T (grass)	Snow depth	T (ground)	Ground cond.
00:00 18:00[1]		–		–
06:00 00:00		–		–
12:00 06:00		–		–
18:00 12:00		–		–

4.11.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure Sea level mm (hPa)	Pressure @ [illegible] m mm (hPa)	Rel. humid.	Dew point	Wind, ave. direction - speed (gust)	Visibility	Cloudiness	Cloud base above (km)	Conditions (SYNOP code)
00:00 18:00[1]	+2[illegible]°C	7[illegible] (101[illegible])	[illegible] (101[illegible])	[illegible]%	[illegible]°C	0 (–)	[illegible] km	[illegible]%	[illegible] m ( )	
06:00 00:00	+2[illegible]°C	7[illegible] (101[illegible])	[illegible]	[illegible]%	+[illegible]°C	0 (–)	[illegible] km	[illegible]%	[illegible] m ( )	(05) Haze
12:00 06:00	+31.[illegible]°C	7[illegible] (101[illegible])	[illegible]	[illegible]%	+[illegible]°C	0 (–)	[illegible] km	[illegible]%	[illegible] m ( )	
18:00 12:00	+[illegible]°C	7[illegible] (101[illegible])	[illegible]	[illegible]%	+[illegible]°C	0 (–)	[illegible] km	[illegible]%	[illegible] m ( )	
Mean	+2[illegible]°C	7[illegible] (101[illegible])	[illegible] (101[illegible])	[illegible]%		0 m/s		[illegible]%		

Local time displayed in Local Standard Time at station location (without correction for daylight saving).

GMT to Local Standard time conversion used for station Dhaka (41923): Local Standard time = GMT +6:00

Done

Russia's Weather Server >> Weather Archive >> Asia >> Bangladesh >> Dhaka (#41923)

Search. Name starts with Find it!

Dhaka (#41923) -- Bangladesh

Date	Data source (weather station) Export data for time period to text file	Date selector
Step day back 6 November 2009 Step day forward	Dhaka - #41923 (23°46'N 90°23'E)	Receive data for date selected
	Altitude above sea level: 9 m	

6.11.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night subseq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

6.11.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 / 18:00[1]	-	-		
06:00 / 00:00		-		
12:00 / 06:00				
18:00 / 12:00				-

6.11.2009 - Hourly observations (atmosphere)

Time local / GMT	Air temp.	Pressure @sea level mm (hPa)	Pressure @9 m mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base & code (cm)	Conditions (SYNOP code)
00:00 / 18:00[1]	-24.4°C	760 (1013)	759 (1012)	85%	+22.0°C	0 ( )	4.0 km	80%	250 m ( )	(05) Haze
06:00 / 00:00	-24.9°C	759 (1013)	759 (1012)	94%	+[illegible]°C	0 ( )	4.0 km	40%	450 m ( )	(05) Haze
12:00 / 06:00	-33.4°C	759 (1012)	758 (1011)	61%	+21.0°C	0 ( )	5.0 km	40%	450 m ( )	(05) Haze
18:00 / 12:00	+25.5°C	757 (1009)	755 ([illegible])	72%	+23.0°C	0 ( )	5.0 km	40%	450 m ( )	(05) Haze
Mean	+26.0°C	759 (1012)	758 (1011)	78%		0 m/s		50%		

Local time displayed is Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion used for station Dhaka (#41923): Local Standard time = GMT+6:00

Rusia's Weather Server >> Weather archive >> data >> Bangladesh >> Dhaka (41923)

Dhaka (41923) – Bangladesh

Date	Data source (weather station) Export data for time period to text file	Date selector
Step day back 19 November 2009 Step day forward	Dhaka 41923 (23°46'N 90°23'E) Altitude above sea level 9 m	Process data for date selected

19.11.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night sum)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

19.11.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 - 18:00[1]	-	–		–
06:00 - 00:00		–		–
12:00 - 06:00		–		–
18:00 - 12:00		–		–

19.11.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @sea level mm (hPa)	Pressure @9 m mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base above (feet)	Conditions (SYNOP code)
00:00 / 18:00[1]	+24.0°C	[illegible]	[illegible]	79%	+20.0°C	0 (...)	4.0 km	40%	250 m ( )	
06:00 00:00	+21.5°C	[illegible]	[illegible]	10%	[illegible]	N (360°) - 2 (...)	4.0 km	-	3000 m ( )	
12:00 - 06:00	+27.2°C	[illegible]	[illegible]	30%	+14.0°C	N (360°) - 2 ( )	4.0 km	30%	3000 m ( )	(05) Haze
18:00 12:00	+25.0°C	[illegible]	[illegible]	71%	+18.0°C	0 (...)	3.0 km	30%	3000 m ( )	(05) Haze
Mean	+25.3°C	[illegible]	[illegible]	57%		1 m/s		50%		

Local time displayed is Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion as set for station Dhaka (41923): Local Standard time = GMT +6:00.

Done

Dhaka (41923) – Bangladesh

Date	Data source (weather station)	Date selector
Step day back 17 November 2009 Step day Forward	Export data for time period to text file	Get new data for date selected
	Dhaka 41923 ([illegible])	
	Altitude above sea level: 9 m	

17.11.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night sub-seq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

17.11.2009 - Hourly observations (surface)

Time	T (snow)	Snow depth	T (ground)	Ground cond.
00:00 - 18:00[1]				-
06:00 - 00:00				-
12:00 - 06:00		–		–
18:00 - 12:00				-

17.11.2009 - Hourly observations (atmosphere)

Time local - GMT	Air temp.	Pressure @sea level mm (hPa)	Pressure @9 m mm (hPa)	Rel. humid.	Dew point	Wind m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base (lowest)	Conditions (SYNOP code)
00:00 - 18:00[1]	+[illegible]°C	[illegible] (1010)	[illegible] (1009)	[illegible]%	+[illegible]°C	0 (-)	4.0 km	30%	450 m ( )	(05) Haze
06:00 - 00:00	[illegible]°C	[illegible] (1010)	[illegible] (1009)	[illegible]%	+[illegible]°C	0 (-)	4.0 km	40%	450 m ( )	(05) Haze
12:00 - 06:00	+[illegible]°C	759 (1012)	[illegible] (1011)	[illegible]%	+[illegible]°C	[illegible] ([illegible]) - 1 (-)	4.0 km	70%	450 m ( )	(05) Haze
18:00 - 12:00	+[illegible]°C	[illegible] (1010)	[illegible] (1009)	[illegible]%	+[illegible]°C	0 (-)	4.0 km	[illegible]%	[illegible] m ( )	(05) Haze
Mean	+26.2°C	758 (1010)	757 (1010)	67%		0 m/s		40%		

Local time displayed is Local Standard Time at station location (without correction for daylight saving).
GMT is Local Standard time corresponding to the station Dhaka (41923). Local Standard time = GMT +6:00.

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Dhaka (41923) -- Bangladesh

Date	Data source (weather station) Export data for time period in text file	Date selector
Step day back 20 November 2009 Step day forward	Dhaka 41923 (CTMN 99778)	- Receive data for date selected
	Altitude above sea level [illegible] m	

20.11.2009 - Daily summary

Temperature		Precipitation	
Mean		24 hrs (day + night subseq.)	
Maximum		Day	
Minimum		Preceding night	
Min. ground T		Sunshine duration	

20.11.2009 - Hourly observations (surface)

Time	T (water)	Snow depth	T (ground)	Ground cond.
00:00 18:00[1]		–		–
06:00 00:00		–		.
12:00 06:00		.		..
18:00 12:00		.		–

20.11.2009 - Hourly observations (atmosphere)

Time local GMT	Air temp.	Pressure @sea level mm (hPa)	Pressure @St. mm (hPa)	Rel. humid.	Dew point	Wind, m/s direction - speed (gust)	Visibility	Cloudiness	Cloud base (lowest cloud)		Conditions (SYNOP code)
00:00 18:00[1]	+20.0°C	763 (1017)	760 (1014)	53%	+12.0°C	0 (..)	4.0 km	..	2000 m ( )	(07) Haze	
06:00 00:00	+21.0°C	763 (1017)	760 (1014)	79%	+1[illegible].0°C	N (270°) - 1 (..)	4.0 km	..	2000 m ( )	(05) Haze	
12:00 06:00	+26.0°C	762 (1016)	760 (1013)	33%	+10.0°C	N (360°) - 2 (..)	3.0 km	..	2000 m ( )	(05) Haze	
18:00 12:00	+22.0°C	760 (1014)	760 (1013)	57%	+16.0°C	N (360°) - 2 (..)	4.0 km	40%	450 m ( )	(05) Haze	
Mean	+22.0°C	761 (1015)	760 (1014)	69%		1 m/s		–			

Local time displayed in Local Standard Time at station location (without correction for daylight saving).
GMT to Local Standard time conversion used for station Dhaka (41923): Local Standard time = GMT+6:00

Done

Annexure A4

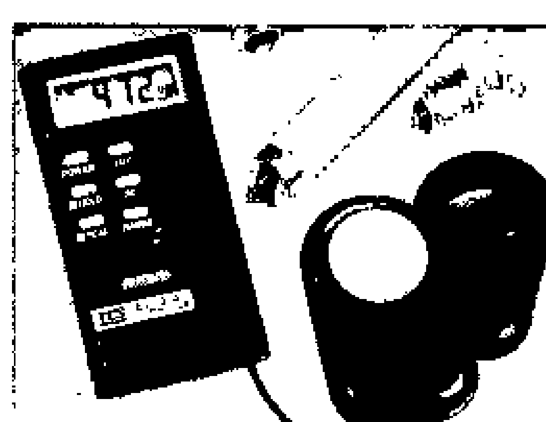
TES 1332 Digital Lux Meter

SPECIFICATIONS

- Display: 3-1/2 digit LCD
- Measuring Range: 20/200/2000/20000/200000 LUX
- Overrange Display: Highest digit of (1) is displayed
- Resolution 0.1 LUX
- Accuracy: ± 3% rdg ± 0.5 %(Calibrated to standard incandescent lamp.2856°K)
- Spectral response CIE Photopic (CIE human eye response curve)
- Spectral Accuracy: CIE V□ Function f'1<=6%
- Repeatability: ± 2%
- Temperature Characteristics: ± 0.1% /°C
- Measuring Rate: Approximately 2.0 time/sec
- Photo sensor: Silicon Photodiodes
- Operating Temperature and Humidity: 0°C~40°C(32°F~104°F) & 0~80% RH

Ranges (LUX)	Allowance
0-200/0.1	± 3% rdg ±0.5%
0-2000/1	f.s. (<10000 LUX)
0-20000/10	± 4% rdg ±10 dgt
0-200000/100	f s (10000LUX)

FEATURES



- Accurate and instant response
- Data hold function
- Special sensitivity close to CIE photopic Curve
- Cosine Angular corrected
- Analog output jack for recording
- CNS 5119 class II