ASSESSMENT OF THERMAL COMFORT OF NON-AIRCONDITIONED IN-PATIENT HOSPITAL WARDS IN DHAKA DURING WARM HUMID PERIODS

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The thesis titled **"ASSESSMENT OF THERMAL COMFORT OF NON-AIRCONDITIONED IN-PATIENT HOSPITAL WARDS IN DHAKA DURING WARM HUMID PERIODS"**, submitted by Sadia Israt Anam, Roll No: 1015012004 [F], Session October 2015, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of **MASTER OF ARCHITECTURE** on 19th February, 2018.

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List of Nomenclature

ANSI= American National Standard Institute

ASHRAE= American Society of Heating, Refrigerating and Air Conditioning Engineering

AT=Air Temperature

AV=Air Velocity

BMD=Bangladesh Meteorological Department

BNBC= Bangladesh National Building Code

BUET= Bangladesh University of Engineering and Technology

$^{\circ}$ C =Degree Celsius

DBT= Dry Bulb Temperature

HVAC= Heating, Ventilating and Air-Conditioning

IAQ= Indoor Air Quality

IEQ= Indoor Environmental Quality

ISIAQ= International Society of Indoor Air Quality and Climate

ISO=International Organization for Standardization

NT=Neutral Temperature

NV= Naturally Ventilated

PMV= Predicted Mean Vote

PPD= Predicted Percent Dissatisfied

RH= Relative Humidity

TSV=Thermal Sensation Voting

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Abstract:

Thermal comfort is an important factor for creating a comfortable indoor environment and ensuring good health for the occupants of a tropical country like Bangladesh, where most of the in-patient hospital wards are highly dependent on natural resources for lighting and ventilation. Unlike healthy populations, the thermal comfort requirements of patients are quite variable which has not been studied in the context of Bangladesh yet, especially during warm humid periods. This research aimed to understand the effect of indoor thermal condition on patient's perception, thermal sensation and thermal comfort level in non-air conditioned in-patient wards of the case study hospital. It also tried to identify 'Neutral' and 'Preferred' air temperature and relative humidity of occupants in the studied context. 400 data were collected from a combination of qualitative and quantitative methods; objective measurement of the environmental parameters (air temperature, relative humidity and air velocity) were collected with proper instruments and subjective assessment of questionnaire survey were conducted on 200 adult patients of Medicine and Surgery wards during warm humid periods. Through statistical methods patient's comfort range for this period of the year were identified, which was 29.46 - 31.46ºC and 77.4-83%. The 'neutral' temperature and relative humidity of patients were identified as 30.45^{O}C and 80.3% respectively whereas the 'preferred' air temperature and relative humidity were 30.26^{O}Cand 79.8%, which are much higher than the international standard but complied with the previous findings in the context of Bangladesh. Although more than 90% patients have voted their existing condition within acceptable range of comfort, 54.75% of them voted their thermal condition as 'not comfortable'. So, more comprehensive investigation is required following the methodology adapted in this research, to establish the contextual requirements of thermal condition in non-air-conditioned In-patient wards of Hospitals during warm humid periods for Dhaka that can lead to formation of local design guidelines.

CHAPTER 1: INTRODUCTION

Background

Problem statement

Objective of study

Research methodology

Significance of the study

Validation of results

Structure of the Thesis

1.1 Background

Thermal comfort is a significant factor for creating a comfortable indoor environment, and for ensuring good health for its occupants, especially for a tropical country, like Bangladesh (Appah-Dankyi and Koranteng, 2012). According to ASHRAE 55-2004 (2004), thermal comfort can be considered as a subjective response. It is defined as the state of mind that expresses satisfaction with the existing environment (Brager and Richard, 1998), as the state of mind is widely driven by perception and expectation of the occupants. In contrast, 'thermal sensation' is a rational experience, which is dependent on activity-thermo receptors in the skin (Hansel, 1981), and can be described in objective terms like 'cold' or 'warm'. Although occupants perception of thermal comfort sensation can be different, even in the same thermal environment (Brager and Richard, 2002) (Auliciems, 1981) (Rajasekar and Ramachandraiah, 2010), there is a set of general conditions of environmental variables (air and radiant temperatures, airflow, humidity etc.), in which a majority of the people would be at ease (Mallick, 1994). From the acceptable temperatures that are based on associating ideal conditions of neutrality, a 'comfort zone' or 'comfort range' can be identified (Brager and Richard, 2002). 'Thermal neutrality' for a person, is the condition in which the subject would prefer neither warmer, nor cooler, surroundings (Fanger, 1972). Thermal preference is more related to user's expectation or preference of thermal condition.

Temperature and Humidity are two of the prime indicators of thermal comfort. People in tropical regions tend to tolerate both higher temperatures and relative humidity levels due to acclimatization (Ahmed, 1994) (Mallick, 1994). As international standards and related predictive models were originated, and mainly make prediction for subjects in cool climates, subjects in warm climates often feel differently (Ahmed, 1995). They are tolerant of a significantly wider range of temperatures because of a combination of both behavioural adjustment and psychological adaptation (Brager and Richard, 1998). These results can form the basis of indoor temperature standards, which are more elevated than standards set for cooler climates.

Similar to other buildings types of Bangladesh, most hospital and their in-patient wards are highly dependent on natural resources. The study of thermal comfort in in-patient hospital wards is very important, especially the non-air conditioned ones. These wards are more likely to be affected by the conditions of outdoor environments. A comfortable indoor environment has the capacity to reduce the stress upon patient's health, to achieve psychological stabilization, and can shorten a patient's length of stay in the hospital, by assisting their smooth healing process (Hwang et. al, 2007) (Wagner et al., 2006) (Azizpour et al., 2011). Unlike healthy populations, the thermal comfort requirements of patients are relatively variable. In the absence of studies related to the above, in the context of Bangladesh, a comprehensive research base is necessary, to fill the gap, and for identification of thermal sensation and acceptability of indoor climate by the patients.

1.2 Problem Statement

Thermal comfort requirements for occupants should be assessed during the warm humid season. Design of most buildings is dependent on the thermal comfort of their occupants. This need is even greater for hospital designs. Patients, who are often sick and in fragile condition, become more sensitive to their surrounding environment, than healthy people (Lenzuni et. al, 2009). Every physiological strain, due to thermal environment, can induce extra undesirable stress, on top of stress related to disease and injury of the patient. According to Gagge and Nishi (1977), due to combined effect of external thermal environment and internal metabolic heat production, the body under goes thermal stress. That is why it is necessary to know about the perception of thermal comfort of patients, which may be different from the healthy population. Depending on the severity of illness, the patients can be less adaptive, and limit their thermal comfort range. Also because of medical treatment and use of drugs, the perception of thermal comfort can be affected. Some studies have already indicated that the indoor thermal conditions of hospitals work as a part of the healing process of patients, and can shorten patient's length of stay in hospital (Azizpour et al., 2011). It was seen through different research findings that patients expect a warmer indoor environment than neutrality, as patients consider cold an uncomfortable sensation, that can increase restlessness, aggravate pain, shivering, inattentiveness, muscular and joint tension, and decrease overall patient satisfaction. [(Wagner et al., 2006) (Fossum et al, 2001) (Sessler et al., 1995) (Vanni et al., 2003), cited in (Khodakarami and Nasrollahi, 2010)] Studies report that the patient's body temperature modulation function is impaired, as a result of weakness, and by creating a comfortable thermal environment, patient's mood could be stabilized and a faster healing is possible (Hwang et. al, 2007). But, for the last few decades, only a handful of research has been done on the thermal comfort requirements in hospital buildings and their occupants, like patients and medical personnels, in different regions of the world.

Bangladesh is located in a tropical region, where the air temperature and relative humidity is quite high. So like other tropical countries Bangladesh also showed deviation in thermal comfort requirements in different seasons, from the International standards like ASHRAE or VIPA. Previously Ahmed Z. N. has conducted extensive research conducted on the thermal comfort requirements of the occupants in residential buildings of Dhaka, which have revealed some deviation from these standards (Ahmed, 1987) (Ahmed et. al., 1990) (Ahmed, 1994). Later multiple studies on different building types have indicated similar results as well (Mallick, 1994) (Shahjahan, 2012) (Fatemi, 2012) (Tariq, 2014). So, like any other buildings of Bangladesh, there is a certain possibility of some deviation of standards in the comfort requirement of patients in Hospital environment also. Most of the district hospitals are highly depended on natural resources like natural ventilation, day lighting etc. due to limitation of artificial sources. So, indoor environments tend to change with the outdoor atmosphere and seasons of the year. As a result the same building doesn't feel comfortable at different seasons. Along with the environmental differences, clothing styles, culture and use of naturally ventilated buildings etc. work as important factors to determine the user's preference of satisfaction. Researchers have elaborated another crucial factor for developing countries. Often a person is obliged to accept his situation due to their Inevitability of the climate of a place whether it is better or worse sensation of their comfort level (Mallick, 1994) which is especially true for poorer population of developing countries. So, there is a higher possibility of variation in perception of indoor thermal environmental and comfort conditions of occupants in developing countries compared to developed western (usually colder) countries where the earlier studies were conducted.

Little research was found on hospital buildings and its thermal comfort conditions in context of Bangladesh and this study aim to fill that gap. Moreover, though thermal comfort studies have been conducted for Dhaka's particular climate (Ahmed Z.N., CIBSE Publication; Mallick, 1994), they have not focused on any particular building type. It is clear, however, from the previous discussion, that the thermal comfort requirement of hospital patients is likely to differ from those of other occupants. The main aim is to understand the indoor thermal environment of typical ward layouts of Government teaching hospitals of recent times, and their occupant's perception of comfort there. The findings of this research will help to establish the contextual requirements of thermal condition in non-air-conditioned In-patient wards of Hospitals during warm humid periods for Dhaka that can lead to formation of local design guidelines.

1.3 Objective of study

This study aims to investigate patient's 'sensation', 'comfort', 'acceptability' and 'preference' regarding indoor environment of non-air conditioned in patient wards of Dhaka during warm humid period (June – September) that is considered to be the most critical period of the year/climate, and to compare the findings with established comfort models. The research aims to suggest a combination of environmental variables (AT, RH and AV), to attain comfortable indoor climate and to improve the current conditions. The research objectives are summarized below:

1. To inspect the existing thermal condition of non-air conditioned in-patient wards and to compare them with acceptable thermal standards.
2. To understand patient's thermal sensation, comfort and preference in the non-air conditioned in-patient wards and to compare the findings with internationally recognized comfort adaptive models (ASHRAE, ISO etc.).
3. To identify the combination of thermal conditions (AT, RH and AV), which will be perceived as comfortable by most of the patients in the context of Dhaka.
4. To identify 'Neutral' and 'Preferred' temperature and relative humidity of occupants in the studied context.

1.4 Research methodology

The aim is to identify the range of conditions comfortable for the occupants in hospital wards of Bangladesh, within the available adaptive opportunities and climatic context, with especial reference to Dhaka region. This research will follow the methodology outlined below (in four phases).

Phase 01: Literature Review:

To frame the knowledge base, various established thermal comfort models along with indoor thermal comfort research focusing on various psychological, behavioural, and other complex adaptive systems as contributory factors for comprehensive feeling of thermal comfort as complex adaptive system will be studied. This will also help to identify relevant independent variables having significant relationship with indoor thermal comfort, with respect to Dhaka's climatic condition. Related meteorological data for Dhaka region will be analyzed from authentic published information. Moreover, common practices for designing in-patients wards of both home and abroad, along with standards (national and International) and earlier thermal comfort studies on hospital wards at other countries will be discussed as well.

Phase 02: Field Survey:

a) Reconnaissance survey:

Prior to detailed field investigation a pilot survey was undertaken, to finalize the process of sample selection and the format of the questionnaire (Section 3.3).

b) Detailed field survey:

After the pilot survey a detailed field survey was conducted by following these steps:

i) Selection of in-patient wards was based on physical features of spaces, positions of doors, windows and ceiling fans. All of these data were measured and recorded on a datasheet along with sample's location and recording positions of measurements.

ii) Two-hundred representative patients were selected by random sampling process after neutralizing all other influencing factor. Selected patients were wearing regular summer clothing (within 0.24-0.5 clo) and have a low activity level between 'reclining' to 'seated, at rest' (within 0.7-1.0 met), and were exposed to no radiant heat.

iii) The survey was conducted only twice (Morning and noon of the same day) on each sample patients in the selected inpatient wards during the period June to September through a questionnaire to record their perception and preference along with extensive observations on behavioural adjustments of individual subjects.

iv) Simultaneously, air temperature, relative humidity and air velocity data were collected at 1meter height from the ground (at the level of patient's bed) using measuring instruments and without any exposure to radiant heat.

Phase-3: Analysis and result:

All the measured data of thermal conditions were analyzed through structural analysis which is common practice for case-study research. The structural analysis is used to categorize, tabulate and recombine the qualitative data (collected through questionnaire survey) and quantitative data (collected by instruments) to reveal the answers of the set research questions. All the collected data was analyzed by placing information, through specific techniques (including creating various tables, graphs and excel spreadsheets, which is further elaborated in Chapter 4) in order to examine trends and generate preferable thermal condition by the patients.

The Schematic Diagram of Research Methodology of this study is as follows:

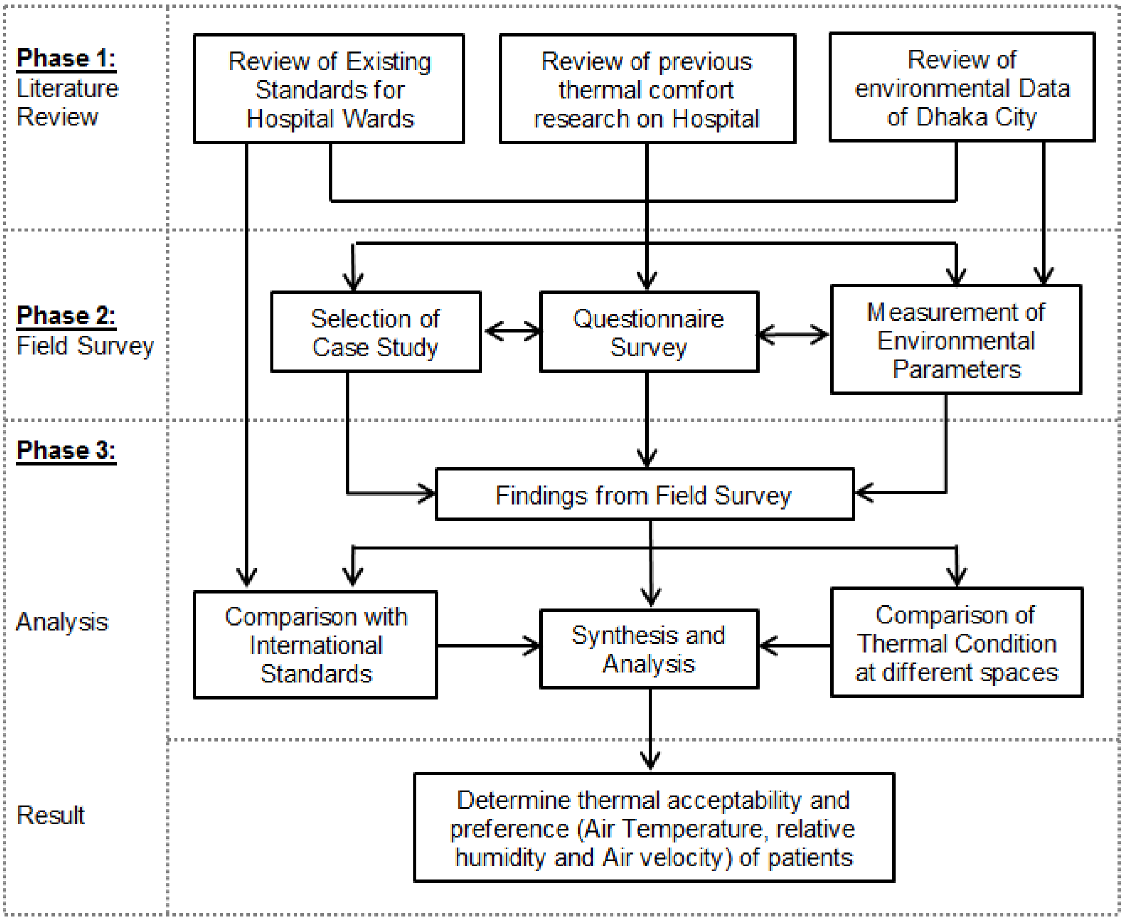

Figure 1.1 Diagram of Research Methodology

1.5 Significance of the study

The research mainly focused on observing the existing thermal conditions in non-air-conditioned in patient wards of Dhaka, to assess occupants' thermal sensation and perception regarding the indoor thermal condition. The outcome of this research tried to provide some baseline information and to establish the contextual requirement of thermal condition, that can be used to design non air-conditioned in patient wards, which are thermally comfortable for patients.

This research also analyzed the behavioural adjustments, adopted by the patients, to study the passive methods of achieving thermal comfort inside hospital buildings. Behavioural adjustments are often considered as the best solution to provide a healthy and energy-efficient indoor environment (Supic, 1982) (Sharples and Malama, 1996) (Sharples and Malama, 1997) (Jingxia, 1996).

This issue has yet to be addressed by researchers in the context of Bangladesh. So, the findings of this research are a new addition to the comfort studies for Bangladesh. Moreover, identification of ‘neutral’ and ‘preferred’ environmental parameters for this tropical region, will contribute to the knowledge segment of thermal studies of Bangladesh as well as this tropical region.

1.6 Validation of results

Triangulation is the process of cross-checking by using multiple methods and data sources to enhance the validity of research findings (Mathison, 1988). It strengthens a study by combining several kinds of methods (using both qualitative and quantitative approaches) or data (Patton, 2002), which is an important way of ensuring the validity of case study research (Johansson, 2003). The case study method provides researchers the opportunities to verify and cross check data, in order to strengthen the research findings and conclusions, due to its use of multiple data collection methods and analysis techniques (Garson, 2002).

Among the four types of triangulation (Denzin, 1978), data triangulation and method triangulation were used in this study. Two different instruments were used to investigate the existing air temperature of the in-patient wards for data triangulation, and for method triangulation, the personal factors and behavioural adjustments were observed, as well as sample patients responses were collected by a questionnaire survey, and matched with the previous findings.

1.7 Structure of the Thesis

The overall structure of this research is organized in the following chapters.

1.7.1 Chapter 1: Introduction

This introductory part of the thesis mainly states the current research problem and attempts to rationalize the background with relevant published data and research findings along with research objectives, research methodology and significance of this indoor thermal comfort study.

1.7.2.1 Chapter 2: Section-A: Literature Review on Indoor Thermal Comfort

This chapter tries to define the key components of this research along with its overall importance through established knowledge resources from published research. Also, the relevant factors influencing indoor thermal comfort and appropriate research approaches along with comfort models are identified to prepare the overall base for this study.

1.7.2.3 Chapter 2: Section-B: Climate of Dhaka

This chapter portrays a general climatic overview of Bangladesh mainly focusing microclimate of Dhaka region to formulate an environmental database for further analysis and to select the most critical part of the year for field investigation based on authentic published information from secondary data sources.

1.7.2.3 Chapter 2: Section-C: Healthcare architecture practices and Thermal comfort research on In-patient wards

This chapter elaborates the general situation of Healthcare architecture and practices of Bangladesh. Review on the formation and evolution is discussed based on previous research findings and published data from secondary sources. Finally the current research problem is justified through the analysis on the typical in-patient ward layouts and possible thermal comfort problem. Both international and national standards along with other thermal comfort studies on in-patient hospital wards at different region of the world are discussed in this chapter.

1.7.3 Chapter 3: Field Investigation

This chapter elaborates the overall outline on field survey is explained including selection of hospitals, in-patient wards, sampling strategies, pre survey works etc. along with justification of survey period, survey location and sample age group. Finally total data collection processes along with measurement techniques is discussed in details.

1.7.4 Chapter 4: Result and Analysis

To obtain a meaningful result and findings related to the research objectives, subjective and objective responses of sample patients and analysis of the entire collected data are presented in this chapter. Trends are examined and the findings are presented of ‘neutral’ and ‘preferred’ air temperature and relative humidity.

1.7.5 Chapter 5: Conclusion and Recommendation

This thesis is concluded in this chapter through summarization of the overall findings based on the analysis of data obtained from field investigation, limitations and some general recommendations along with directions for future research in the field of indoor thermal comfort.

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CHAPTER 2: SECTION-A

LITERATURE REVIEW ON INDOOR THERMAL COMFORT

Definition of Thermal Comfort

Importance of Thermal Comfort

Thermal comfort parameters

Comfort zone and environmental indices

Thermal comfort research approach

ASHRAE Standards for thermal comfort

Previous indoor thermal comfort studies in tropics

Thermal comfort studies in Bangladesh

Types of analysis

2.1.0 Introduction

For the last few decades, emerging issues like climate change, sustainability and sustainable development etc. have contributed to numerous researches on indoor thermal comfort. This chapter will explore and analyze the existing knowledge base, design strategies and techniques, regarding occupant's perception of indoor thermal conditions, which will help to structure the current research.

2.1.1 Definition of Thermal Comfort

The most widely used definition of thermal comfort was introduced by ASHRAE (1966), quoted as "*Thermal comfort is a condition of mind that expresses satisfaction with the thermal environment"* (ASHRAE-55 1992; ISO 1984, ASHRAE 55-74). Subsequent definitions of thermal comfort provided by different authors emphasized on the notion of thermal neutrality. Thermal neutrality was first defined by Fanger (1972) as *"*a condition in which the subject would prefer neither warmer nor cooler surroundings*."* The author stated that the satisfaction with the thermal environment is mainly based on the heat balance of human body which is dependent on several parameters, i.e Air temperature (Ta), mean radiant temperature (MRT), relative humidity (RH), relative air velocity (V), and personal parameters: clothing or thermal resistance (Icl) and activity or metabolic rate (M). In a broader sense, 'thermal neutrality' is the condition under which the human body is in a state of thermal equilibrium with its surroundings (Fanger, 1970; Burberry, 1983; Edholme, 1985). According to Hensen (1991), "*Thermal comfort for occupants is a state in which there are no driving impulses to correct the environment by behaviour*".This is very similar to the definition given by Mallick F. (1994) which is, "Thermal comfort for occupants in a building is the condition, where most of the people are unaware of the thermal conditions around them and do not feel the necessity of any adjustments." But attainment of thermal neutrality doesn't necessarily ensure one's thermal comfort. Thermal comfort is considered as more of a state of mind instead of a state condition (Katzschner, 1988). In this sense, thermal comfort can be further defined as "*Thermal comfort is a condition of mind or satisfaction, but the judgment of comfort is a cognitive process involving many inputs influenced by physical, psychological and other factors*" (Lin and Deng, 2008).

As humans can live in different climate zones, there is no absolute standard for thermal comfort. Even when a building is designed as thermally comfortable for its occupants, or with an acceptable indoor temperature, actual responses can still vary from person to person, time to time, locations and situations, depending on one's thermal experience (Shahjahan,

2012) Therefore a comfortable environment is there, where the individual doesn't feel cold or hot. Alternatively it can be defined as the absence of discomfort or stimuli which lead to the change in thermal balance of the body (Ahmed, 1995).

Physiologically comfort can be defined as the situation when there is a thermal equilibrium, in the absence of regulatory sweating, between the heat exchange of the human body and the environment (Fanger, 1970). But the thermoregulation system of human body is influenced by behavioural, physiological and pathological factors, and, therefore differences both within and between individuals exists (Van *et. al.,* 2002). As a result, even in the same environment thermal sensation of different people can be varied. Even when persons are subjected to the same climate, have occupied similar spaces and belonged to a common culture, their opinions of thermal comfort can be very different. This variation is usually the result of the combination of multiple numbers of factors that affect human perception of thermal comfort. Therefore, to determine the thermal comfort condition of a certain climate, an in depth analysis of the characteristics or parameters of that specific environment and its occupants is required.

2.1.2 Importance of Thermal Comfort

There are several significant and independent parameters which are responsible to ensure the overall indoor environment quality for human comfort. Along with thermal comfort, acoustical comfort, visual comfort, indoor air quality and spatial comfort also contribute to overall Indoor Environmental Quality (IEQ) but not equally. According to Frontczak M. and Wargocki P. (2011), building users consider thermal comfort to be the most important parameter influencing overall satisfaction with IEQ. Fig 3.1 shows that thermal condition is considered to be of higher importance, compared to other parameters, by most researchers (Frontczak and Wargocki, 2011).

Thermal comfort is a significant factor for designing sustainable buildings. It directly affects the energy consumption of a building's environmental systems Yao *et. al*, 2009). Poor comfort often leads to high energy consumption and affects the user's health adversely (Markus, and Morris, 1980) (Stoops, 2004) (Liu, 2007). It is especially true for people living in developing countries of tropical and war humid regions. Moreover, due to increasing population, limited artificial energy and for environmental reason, highest priority should be given to thermal comfort to ensure a comfortable Indoor Environmental Quality (IEQ).

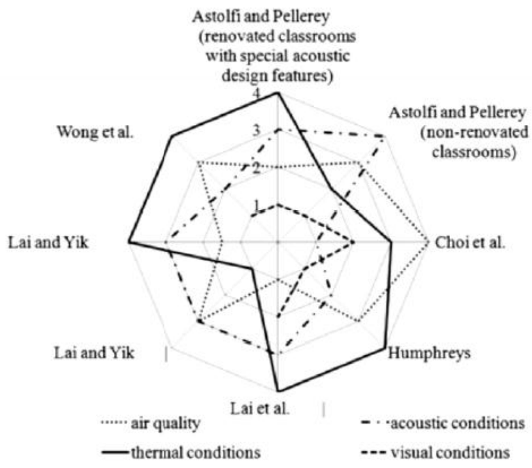


Figure 2.1: Ranking by different researchers of different environmental conditions for overall satisfaction with indoor environmental quality (Frontczak and Wargocki, 2011)

2.1.3 Thermal comfort parameters:

There are numerous factors that can affect the thermal comfort environment in a building, both directly and indirectly. Due to the presence of multiple factors, designing a thermally comfortable indoors becomes more complex. Physiology, psychology, climate and building design are considered to be the most influential factors among them. Some of these factors are dependent on environment conditions, whereas others are deductive from socio cultural point of view. Some of them can be quantified, while others cannot be directly estimated or controlled. But each can have both independent and dynamic influence on the thermal comfort perception of occupants.

Physiology and psychology are the two factors that dynamically influence user's response, regarding their thermal sensation and perception of indoor environment. Climatology cannot be modified easily, and people always adapt to the climate conditions where they live. Built environment affects local and regional climate change, that can influence comfort and health (Basselmann, 1995). So, building design also has a significant influence on thermal comfort of occupants (Ahmed, 1987; Ahmed, 1994; Mallick, 1994). The factors that can influence thermal comfort, can be divided into the following three broad categories.

1. Physiological Factors
2. Psychological Factors
3. Environmental Factors
    a. Micro Environmental Factor (Building Design)
    b. Macro Environmental Factor (Climatology)

2.1.3.1 Physiological Factors

2.1.3.1.1 Mechanism of Thermoregulation

Thermal comfort is more related to the thermoregulation system of human body. According to Hansel (1981), this system is very complex and incorporates more control principals, compared to any actual technological control system. It behaves mathematically in a highly non-linear manner. Also, it contains multiple sensors, feedback loops and outputs. (Shahjahan, 2012)

The basic process of heat exchange is comprised of the following steps. Firstly, human body produces heat mainly by metabolism. Then, it exchange heats with the environment via radiation and convection. Finally the body loses heat by evaporation of body fluids. (Shahjahan, 2012) The process involved, in converting foodstuff into living matter and useful form of energy, is known as metabolism (Koenigsberger *et. al.*, 1973). This metabolic heat production can be of two kinds: Basal metabolism (biological processes which are continuous and non-conscious) and Muscular metabolism (during work, which is consciously controllable, except in shivering). Table 2.1 shows some typical metabolic rates, which can be expressed in a unit devised for thermal comfort studies, called the met. 1 met = 58.2 W/m^2.

Table 2.1: Metabolic rates at different activities (Source: Energy in Architecture (The European Passive Solar Handbook), B.T. Bats Ford Limited, 1992).

Activity	**Met**	**W/m^2**
Sleeping	0.7	40
Reclining, lying in bed	0.8	46
Seated, at rest	1.0	58
Standing, sedentary work	1.2	70
Very light work (shopping, cooking, light industry)	1.6	93
Medium light work (house~, machine tool ~)	2.0	116
Steady medium work (jackhammer, social dancing)	3.0	175
Heavy Work (Sawing, tennis)	6.0	350
Very heavy work (Squash, furnace work) upto	7.0	410

The main purpose of the thermoregulatory system, is to maintain deep body temperature at 37^0C, and skin temperature within range 28-34^0C (Koenigsberger *et. al.*, 1973) during heat exchange between human body and its surrounding. To allow adequate heat dissipation, it is required to keep the skin temperature lower than core temperature, and environment temperature lower than skin temperature. A sense of physical wellbeing can be ensured in such environmental conditions, and it can be considered as comfortable indoor environment (Tariq, 2014).

Table 2.2: Critical body temperature (an approximate guide) (Auliciems, and Szokolay, 2007)

Feeling	Skin Temperature	Deep Body Temperature	Regulatory Zone
Pain	45^0C	42^0C	Death
		40^0C	Hyperthermia
			Evaporative Zone
			Vasodilatation
Comfort	$31\text{-}34^0C$	37^0C	Comfort
Pain	10^0C		Vasoconstriction
			Thermogenesis
		35^0C	Hypothermia
		25^0C	Death

Autonomic thermoregulation and behavioural thermoregulation are the main two types of thermoregulation of the brain (Passlick, and Bednebender, 2005). The latter one control actions like active movement, adjustment of clothing etc. It is also associated with conscious temperature sensation, and consequent thermal comfort as well (Hensel, 1981).

The main difference, between temperature sensation and thermal comfort is that, the first one is a rational experience, whereas the later one is more like an emotional experience. Temperature sensation can be described in objective terms of ‘cold’ and ‘warm’ whereas thermal comfort can be characterized in terms of ‘comfortable’ and ‘uncomfortable’. As McIntyre (1980) stated, the meanings of words like ‘pleasant’ and ‘comfortable’ do not have an absolute value, but they are more related to experience and expectation. According to Hensel (1981), temperature sensation mainly depends on activity of thermo-receptors in the skin, whereas thermal comfort reflects a general state of the thermoregulatory system. Therefore, the condition of thermal comfort can be defined, as a state where there is no driving impulse to correct the environment by behavior. (after Benzinger 1979).

Other subjective characteristics like age, gender, body composition and acclimatization status can also influence one’s body temperature and energy expenditure (Van, 2002). The effect of age on thermoregulation is still not definite. Some studies found decreased tolerance and deficient thermoregulation with aging, whereas some found similar tolerance and adequate heat dissipation for all age groups (Tsuzuki, 1999). Interestingly, the sensations of men and women regarding skin temperature, were found similar (Mekjavic, et al. 1988) (Modera 1993) and the influence of genetic composition, is still unknown to great extent (Van, 2002).

2.1.3.1.2 Physical adaptation

Physical adaptation can be defined, as changes in physiological response, due to exposure of different thermal environmental factors, which often lead to a gradual diminution in the strain induced by such exposure (Brager and De Dear, 1998). Physical adaptation can be classified into the following two sub categories (Brager and De Dear, 1998).

i) Genetic adaptation

The alternation that is developed at time scales that is beyond an individual lifetime, and later become a part of their genetic heritage of that individual, or group, of people, can be defined as genetic adaptation. (Shahjahan, 2012)

ii) Acclimatization:

The changes in the setting of physiological thermoregulation system, over a period of days or weeks, due to exposure to a single, or a combination, of thermal stresses, can be defined as acclimatization. In other words, the changing process in a person's physiological thermoregulation set points, due to prolonged exposure to climatic conditions, outside the traditional comfort zone, can be defined as acclimatization (Fountain, 1996). Humphreys (1996) suggests that comfort is "context-dependent" or"situational", a way of understanding results, that is related to both experience and expectation, both physiological and psychological. Many of these studies identified that the comfort temperature for occupants in tropical countries, and in locations with high outdoor temperatures, is much higher compared to other climatic zones (Busch, 1992) (Kwok, 1998).

2.1.3.1.3 Clothing

Clothing, is considered as one of the most powerful means of behavioural thermoregulation, to attain comfort or neutrality (Parsons, 2003). Many researchers identified clothing, as a modifier or insulator for body's heat loss, heat gain, and comfort (Shahjahan, 2012). Clothing adjustment, itself, works as a personal thermal comfort moderator. But if it is further combined with adaptive actions, taken by the occupants, it has a greater effect in reducing energy consumption in residential buildings (Newsham, 1997). Clothing is a dominant factor, that especially affects the heat dissipation in the tropical context. The thin clothing enhances evaporative heat loss by acting as a mesh, and allowing wind action directly to the skin, in hot humid environmental condition (Ahmed, 1995).

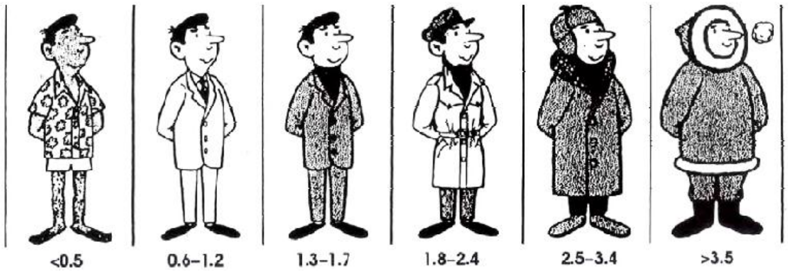


Figure 2.2 Insulation of clothing in clo units

(Source: Based on ASHRAE 1985, from Auliciems and Szokolay 2007)

To measure insulation in the field of thermal comfort studies, a unit has been introduced, named 'clo'. ISO have standardized estimation of the thermal insulation and evaporative resistance of clothing ensembles from numerous research findings (ISO 9920 1995) (Fig 2.2). The clo value of a normal business suit is '1' (Fig 2.2), whereas light summer clothing, which is very common in tropical environment, has a clo value ranging between .35-.5 clo (Fig 2.3, from Mallick 1994). Apendix-01 shows the clo-values of various pieces of garments. The total clo value of an ensemble is 0.82 times the sum of individual items. (Auliciems and Szokolay, 2007)

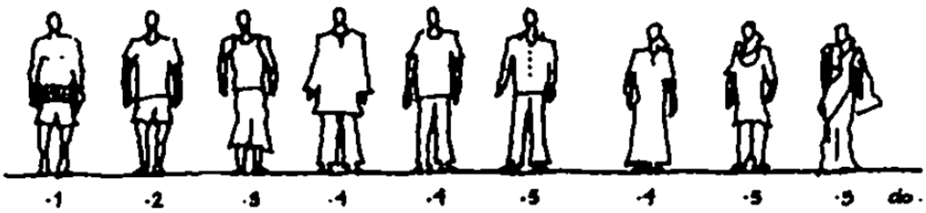


Figure 2.3: Typical clo values in the context of Bangladesh (Mallick, 1994)

2.1.3.2 Psychological Factor

Researchers have found that occupant's behaviour and indoor environment condition is a connected process. Environmental conditions not only determine an occupant's behaviour (adjustment, control), but influence the way the occupant modifies any uncomfortable conditions (Raja, 1998) (Feriadi, 2003). Environmental modifications, like operable windows, blinds, fans, other personal behavioural adjustments (Iwashita and Hiroshi, 1997), etc. can help to create an effective indoor thermal comfort condition, as well as, can satisfy an occupant's preference, of higher controllability in naturally ventilated buildings. Some researchers also found, that people tend to reduce their activity level, or change their posture, as an unconscious action, to adapt in warmer environments (Olesen and Parsons, 2002; Fanger and Toftum, 2002; Baker and Standeven 1996).

Individual control of local environment, is considered to be the best solution from the point of view of satisfaction and comfort (Fountain, 1996). Thermal dissatisfaction can be caused due to lack of understanding of these controls (Parine and Peplow, 1999). Increased control, over indoor environment can increase an occupant's thermal comfort, and cause less dissatisfaction, while decreasing energy consumption (Gunnarsen, 2000). On the other hand, based on the way a building is used, occupants may have different expectations. For example, long periods of exposure in air conditioned environments, can affect people's thermal perception, and can result in expectations of higher comfort conditions, compared to people living in naturally ventilated buildings (Feriadi, 2002).

2.1.3.3 Environmental factors

Many researchers have pointed out, that thermal comfort is strongly related to the thermal balance of the body, and this balance is influenced by environmental parameters like: air temperature (Ta), mean radiant temperature (Tr), relative air velocity (v), and relative humidity (RH). (Fanger, 1972) (McIntyre, 1980) (Gagge 1986) (ASHRAE Standard 55-1992R) (Ahmed,1995). Unlike physiological and psychological factors these parameters are quantifiable factors.

2.1.3.3.1 Air temperature (AT)

Air temperature is considered to be the main criterion of human comfort. This environmental factor is measured by dry bulb temperature (DBT), and in degree Celsius (^{0}C). If proper combination of relative humidity and air flow is maintained, thermal comfort can be ensured, for a fairly wide range of temperature. The air temperature must be adjusted, if any one of these parameters varies, to maintain a comfortable indoor condition.

2.1.3.3.2 Relative humidity (RH)

Relative humidity of air affects evaporation rate, as moisture content of the air is related to wetness of skin, which in turns affects comfort sensation (Markus and Morris, 1980). The human body starts perspiring when the air temperature is above 24^{0}C, and this evaporative heat loss is directly affected by humidity and air movement. Convective and radiant heat loss of human body decrease at higher air temperatures and the body generates heat much faster than it can dissipate it. As a result, evaporative losses become more essential, and perspiration alone helps in cooling of the body, from moderate to high temperature. Table 2.3 shows how the level of humidity in air increases a human's perception of temperature, higher than the actual air temperature. Research shows that an increase of 10% in relative humidity has the same effect as a 0.3^{0}C rise in air temperature (Goulding *et. al*, 1992).

Table 2.3: Impact of relative humidity on sensed temperature (Heinen et. al., 1994)

Relative Humidity (%)	Air Temperature (^{0}C)						
	21.1	**23.9**	**26.7**	**29.4**	**32.2**	**35.0**	**37.8**
0	17.8	20.6	22.8	25.6	28.3	30.6	32.8
10	18.3	21.1	23.9	26.7	29.4	32.2	35.0
20	18.9	22.2	25.0	27.8	30.6	33.9	37.2
30	19.4	22.8	25.6	28.9	32.2	35.6	40.0
40	20.0	23.3	26.1	30.0	33.9	38.3	43.3
50	20.6	23.9	27.2	31.1	35.6	41.7	
60	21.1	24.4	27.8	32.2	37.8	45.6	
70	21.1	25.0	29.4	33.9	41.1		
80	21.7	25.6	30.0	36.1	45.0		
90	21.7	26.1	31.1	38.9			
100	22.2	26.7	32.8	42.2			
	Sensed Temperature (^{0}C) ⟷						

2.1.3.3.3 Air Velocity (AV)

Air flow provides fresh air for healthier indoor environment, and thus assists in providing thermal comfort for the occupants. Indoor air velocity plays an important role by creating physiological cooling, when temperature and relative humidity is more difficult to modify. According to De Dear et al (1991), people would prefer breezy air movement in warmer conditions, and less so in cooler environment. Similarly, Li et al. (2010) found that people prefer higher air movement, when there was an increase in temperature. They also added that people tend to welcome the feeling of air movement to still air, even without a cooling requirement related to thermal comfort. Airflow also increases an occupant’s tolerance to higher relative humidity. It also contributes to decreasing overall cooling load of a building, therefore saving energy (Ernest, 1991) (Joswiak, 1996) (Aynsley, 1999). Table 2.4 shows the average subjective reactions, to different air velocities, under regular everyday conditions.

Table 2.4: The average subjective reactions to various air velocities (Auliciems, and Szokolay, 2007)

Speed (m/s)	Subjective reactions
< 0.25	Unnoticed
0.25-0.50	Pleasant
0.50-1.00	Awareness of air movement
1.00-1.50	Draughty
> 1.50	Annoyingly Draughty

2.1.3.4 Building Design

Proper orientation can cause changes of about 5% increase or decrease in total heat load of a building (TERI 2008). According to Ahmed (2004), Building orientation is one of the crucial parameters for ensuring indoor thermal comfort. The author found that the amount of indirect radiation failing on any surface, is almost independent of surface orientation, whereas direct radiation is highly dependent on orientation (Ahmed, 2002). Moreover, buildings should be oriented properly to catch available breeze, which is especially true for tropical countries like Bangladesh (Ahmed, 2002). Again, studies show that along with building orientation, variation in wall thickness can make a significant difference in comfort parameters of house (Mallick,1996) (Ahmed, 2004) .

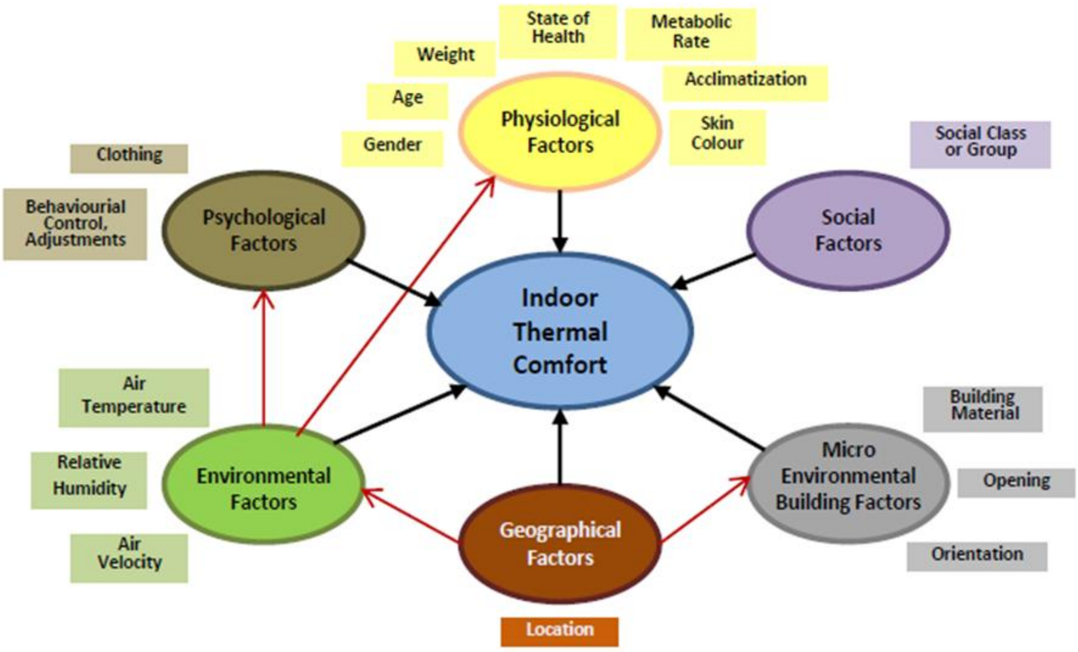


Figure 2.4: Factors influencing Thermal Comfort (Tariq T., 2014)

Moreover, shape and layout of buildings, building surface (both horizontal and vertical), porosity of building envelop (position, type, size and orientation of windows and doors), shading design (over windows, porches etc.) and vegetation can also influence the indoor thermal comfort condition of buildings especially in tropical countries (Ahmed, 2004) (Mallick, 1994). Table 2.5 summarizes the factors that can affect user's perception of thermal comfort according to different studies (Shahjahan, 2012).

Table 2.5: Factors influencing thermal comfort (Shahjahan, 2012)

Factors		**Independent Variables**	**Reference**
Human Factors	Physiological	Metabolic Rate	Givoni 1989, Guyton 1991, Bray 1985
		Acclimatization	McIntyre 1980, Givoni 1998, Guyton 1991, Givoni and Goldman 1973
		State of Health	Mridha 2002
		Skin Colour	Oke 1978
		Age	Ahmed 2003
		Gender	Ahmed 2003
		Weight	Ahmed 2003
	Psychological	Behaviourial Control, Adjustment	Baker1994, Nicol1994, Berger 1990, Ahmed1995
		Clothing	Ahmed 1995, Mridha 2002
	Social	Social Class or Group	Mojumder 2000, Mridha 2002
Macro Environment	Climatological	Air Temperature	Cowan et al, 1983
		Relative Humidity	Givoni 1998
		Air Flow	Koenigsberger, et al 1973; Givoni 1998; Givoni 1995
		Radiation and Mean Radiant Temperature (MRT)	Fanger et al 1985; Olsen et al 1973; Koenigsberger et al 1973; Gouldinget al 1992; Mallick 1994
	Geographical	Location	de Dear et al. 1993
Micro Environment	Building Design	Openings	Ahmed 1994, 2002
		Orientation	Mallick 1994, 1996
		Building Material	Mallick 1994, 1996

From the above discussion, it is clear that numerous factors have been identified, that have either major or minor influences on occupant's thermal perception. To understand the actual impact of macro environmental factors (air temperature, relative humidity and air velocity) on patient's thermal perception, the other factors (physiological, psychological factors and micro environmental factors) are required to be neutralized as much as possible (Details in Chapter-3). For example- age group, height, weight, state of health, skin colour, clothing style, social class etc. should be neutralized to create a baseline for sample selection to avoid too much variation. Only then, authentic data can be obtained from field investigation that will help this study to identify 'neutral' and 'preferred' indoor environment condition which most of the patients will find comfortable.

2.1.4 Comfort zone and environmental indices

2.1.4.1 Comfort zone

According to Brager (2002), "methods for defining a 'comfort zone' or 'comfort range' of acceptable temperatures are based on associating ideal conditions, only with a feeling of neutrality, or being totally unnoticeable." In order to simplify the evaluation, several psychometric and bio-climatic charts have been developed, where thermal comfort issues were considered. In order to define comfort zone, interaction between various climatic parameters were graphically visualized and Olgyay's Bio-climatic chart is the one of the most used chart by researchers and professionals (Olgyay 1973) (Fig-2.5).

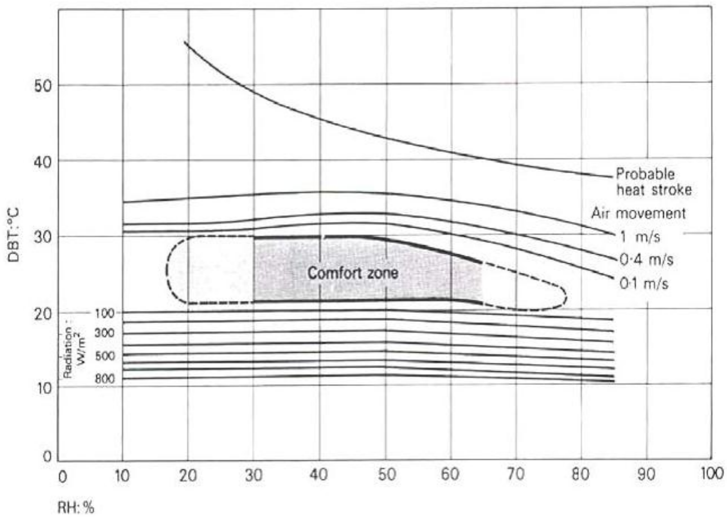


Figure 2.5: Metric version of the bioclimatic chart (Olgyay 1973).

In this bioclimatic chart (Fig: 2.5), the lines above the thermal comfort zone indicate that air movement, at different velocities, can extend the upper limit of the comfort zone. If dry bulb temperature is above the comfort limit, air velocity is required to restore comfort. A group of lines under thermal comfort zone, which indicates levels of radiation, could compensate for lower than comfortable temperatures. To understand whether the current indoor environmental conditions (regarding air temperature, relative humidity and air velocity) falls within the comfort zone or not, Olygay's chart will be used for further analysis (see section 4.3.1)

2.1.4.2 Thermal comfort indices

Any formula, which calculates the effects on subjective response of thermal sensation and comfort due to combination of environmental variables, various levels of activity and clothing, is known as thermal index (Markus and Morris, 1980). There are mainly two methods to understand a user's thermal comfort. The first method, which is used mostly in field studies, investigates through subjective response by questionnaire with simultaneous measurements of environmental conditions. The second method is chamber studies, where suspects are put in controlled chamber or laboratories, where objective measurements of physiological changes, such as sweating, skin wetness or skin temperature are measured.

Empirical-numerical measures (where investigation is done by questionnaire studies, under defined environmental conditions) and analytical methods (where the flow paths from metabolic heat production to the environment, and considering resistances to such flows are traced) are the main two types of thermal comfort indices. (Tariq, 2014)

Among different thermal comfort indices the thermal index proposed by Fanger is widely used, which is called Predicted mean vote (PMV) (Edholme, and Clark, 1985). Based on an empirical numerical model, PMV predicts the mean value of votes of a large group of people on a 7-point thermal sensation scale. Another most popular scale is a 7-point scale [where, -3(Cold), -2(Cool), -1(Slightly Cool), 0(Neutral), +1(Slightly warm), +2(Warm), +3(Hot)] proposed by ASHRAE, which is known as the “ASHRAE Scale” (Butera, 1998). Various scales that are used in thermal comfort evaluation are showed in Table-2.6.

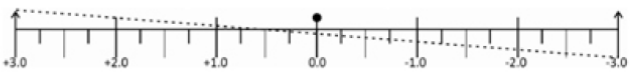
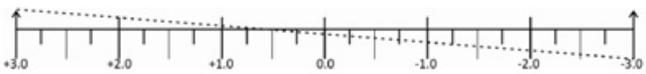
Parameter	**Scales used in subjective evaluation**	**Scale**
Thermal Sensation Vote (TSV)	very hot · hot · slightly cool · neutral · slightly hot · cold · very cold 	ASHRAE Scale
Comfort Sensation	very comfortable · just right · very uncomfortable 	General Comfort Scale
Thermal Preference	extreme hot · much warmer · slightly warmer · no change · slightly cooler · much cooler · extreme hot 	McIntyre Scale

Table 2.6: Scales used in thermal comfort evaluation (Shahjahan, 2012)

PMV index is an established standard, which is acknowledged by ISO standards 7730 (ISO, 1995) and by ASHRAE 55-1992(ASHRAE, 1992). Also, a large number of researchers have used this index for their studies over the years. For the calculation of PMV index, activity

(Metabolic rate) and level of clothing (thermal resistance) have to be estimated, along with environmental parameters (air temperature, mean radiant temperature, relative air velocity and partial water vapour pressure). Although it was developed for steady-state conditions, according to some researchers, it can be applied with good approximation, during minor fluctuation of one or more variables. (Idem. pp. 47)

Effective temperature or ET Index is one of the first thermal indices, referred in ASHRAE, but its disadvantage is that it is independent on clothing and activity which make it impossible to generate a universal ET chart.

To get more reliable information about actual workplace comfort, and the relevant interacting parameters, researchers are currently encouraged to do field studies, in addition to laboratory experiments. As a result, another type of comfort research approach, known as the adaptive approach, is formulated. Its purpose is to analysis the real acceptability of any thermal environment, that is strongly dependent on context, behavior of occupants, and their expectations, which is derived from field studies. (Djongyang *et. al.*, 2010)

During the research, similar types of scales will be used, for gathering data of patient's sensation, comfort and preference, regarding different environmental parameters (Air temperature, relative humidity and air velocity), during interviews, through a standard questionnaire format (see Section 3.5.1)

2.1.4.3 Comfort indices related to adaptability and acclimatization:

Several researchers have indicated about various non-quantifiable elements of comfort, which have influence on an occupant's thermal sensation. Many researchers have suggested a new adaptive model, to calculate both the neutral comfort temperature and the extended PMV model, for naturally ventilated buildings, in warm environments, such as modified PMV (Prianto and Depecker, 2003). On the other hand, Humphreys and Nicol (2002) tried to investigate indoor thermal comfort in naturally ventilated buildings, by plotting field surveyed data against the outdoor monthly mean temperature, at the time of the survey. The results of this study showed a close relationship between indoor comfort temperature and outdoor monthly mean temperatures, in the case of free-running or naturally ventilated buildings.

De Dear and Brager (2002) also propose an adaptive model, as an alternative to the PMV based method in ASHRAE Standard 55, for naturally ventilated buildings. After averaging the comfort zone widths, across all the naturally ventilated buildings used for the study, the reported mean comfort zone band, shown in Fig 2.6, is 5^0C for 90% acceptability, and 7^0C for 80% acceptability, both centered on the optimum comfort temperature. This adaptive comfort standard has been accepted, in the revision of ASHRAE 55 Standards (2003).

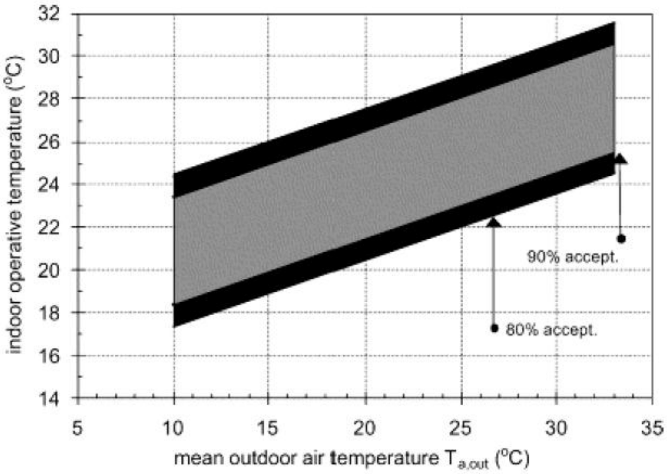


Figure 2.6: Proposed adaptive comfort standard (ACS) for ASHRAE Standard 55, applicable for naturally ventilated buildings (De Dear and Brager 2002).

Again, Fanger and Toftum (2002) argue that the proposed adaptive model, in which the neutral temperature, is related to the monthly average outdoor temperature, suffers from the weakness, of having only one parameter, to evaluate the thermal sensation. In this way, it relegates human factors, such as clothing and activity and the combined effect of the four classical thermal parameters, that have a well-known impact on the human heat balance and therefore on the thermal sensation. As a result, along with measuring environmental parameters, the occupant's activity level and clothing is also required to be documented, for any authentic analysis.

2.1.5 Thermal comfort research approach

Model based, human based and space based approaches are the most commonly used research approaches that are used for studying thermal comfort.

The model based approach is mainly based on simulation of a scaled or virtual model, and can simulate the physical conditions of an indoor thermal environment. It can assess the level of thermal comfort, from certain assumptions and standards, as well as can produce predictive results. The Human based approach is suitable, for comprehensive evaluation, and for developing proper thermal comfort guidelines (standards) (Shahjahan, 2012). It is based on direct investigation of building occupants, in a controlled experiment in a thermal chamber or through a field survey. Finally the space based approach is useful, to evaluate how thermal comfort can be achieved in existing buildings, as it focuses on studying thermal comfort of full scale indoor spaces (rooms). Fig 2.7 shows a general classification of available approaches of thermal comfort studies.

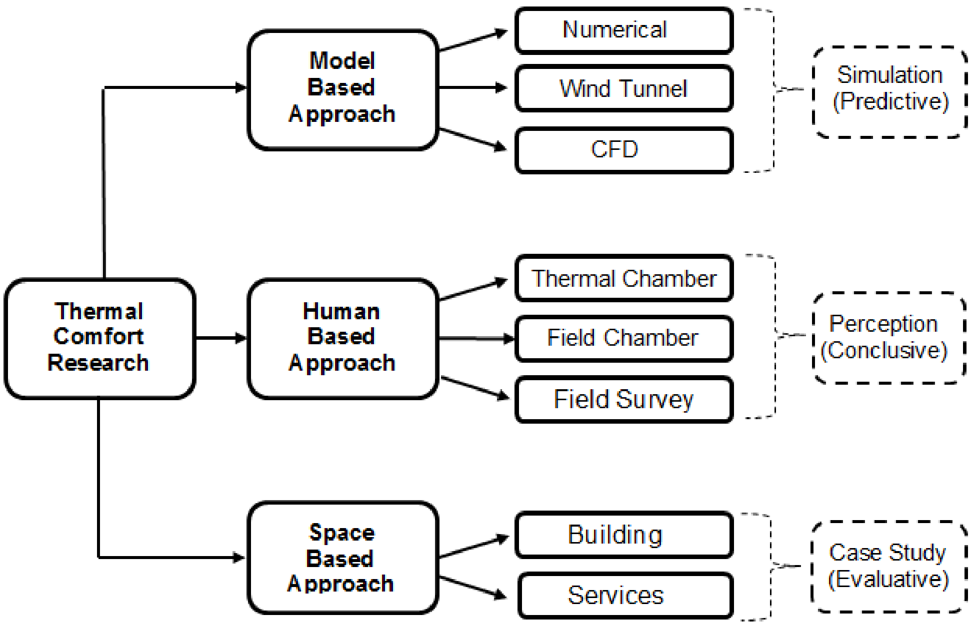


Figure 2.7: Available approaches in thermal comfort researches. (Source: Feriadi, 2003)

Among these approaches, this research will follow the human based research approach incorporating field investigation. It will involve real spaces, where a large number of occupants perform their daily routine, and the integrity of person-environment relationship is retained. As field survey has a multidisciplinary nature, there is a possibility of a number of factors being present, that need not to be considered in a laboratory but they can influence the results of the investigation. However, the influence of local condition and norm of behavior, on perceptions of surveyed groups, is unavoidable, when they belong to different climatic and socio economic regions (Cena, 1993).

Another problem is that, field investigation involves prevalent interaction, between various parameters (Shahjahan, 2012). As a result, it is difficult to determine whether occupant's perceptions and responses, are exclusively for thermal sensation, or whether other fringe factors are influencing these. Again, any subjective self-administrated questionnaire (like that used in this survey), can be difficult to understand by laymen, and can contain responses influenced by related non-thermal parameters (Berglund, 1986).

2.1.5.1 The adaptive approach

Adaptation can be defined as, the gradual reduction of a human's responses, to repeated environmental stimulations, including all processes which building occupants undergo, to improve the 'fit' of the indoor climate, to their personal or collective requirements (Brager, and de Dear, 1998). The adaptive approach is based on field surveys of thermal comfort. It demonstrates, that compared to the suggestion of the laboratory studies people are more tolerant of temperature changes. Human beings consciously or unconsciously take actions which affect the heat balance of the body. These actions include, changing metabolic heat production (changing activity level), changing of the rate of heat loss from the body (Changing clothing level or posture) or adjusting the thermal environment (use of doors, windows, blinds, fans etc.) (Humphreys, 1996). As a result, thermal comfort can be achieved for a wider range of temperatures, than the prediction, of ASHRAE (PROBE, 2001). Adaptive variables are specifically important, for buildings where there is no active heating or cooling systems, known as 'free running' buildings (Nicol, and Susan, 1996). Occupants of such buildings, are required to control their immediate environment by opening and closing windows, using shading (as necessary), and by dressing in a way that can maximize their comfort both indoors and outdoors.

Behavioural adjustments, physiological adaptation and psychological adaptation, are the most distinguished modes of adaptation. Again, behavioural adjustments can be categorized into, personal adjustments, technological or environmental adjustments and cultural adjustments. Personal adjustments include adjustment to the surrounding by changing personal variables, such as adjusting clothing, activity, posture, eating/drinking hot/cold food or beverages, or moving to different locations within the space. Technological or environmental adjustments mean, modifying the surrounding themselves, depending on the availability of control, for example, opening/closing windows or shading devices, turning on fans or heating, blocking air diffusers, or operating other HVAC control, etc. Cultural adjustments include scheduling activities, taking rests, adapting dress codes, etc.

Physiological adaptation can be divided into two categories: genetic adaptation and acclimatization, which has been discussed in earlier section (Section 2.1.3.1.). It takes account, the effect of cognitive and cultural variables, and describes the extent to which habituation and expectation can alter one's perception, and reaction, to sensory information (Brager, and de Dear, 1998). Psychological adaptation means, shifting one's expectation, as a result of having personal control and a history of more diverse thermal experiences (Olsen and Parsons, 2002). The presence of more 'adaptive opportunity' (Baker and Standeven,

1996) and less ‘adaptive constraints’ (Nicol and Humphreys, 2002), which helps people to react and change their comfort situation can contribute to their acceptability towards the thermal environment. According to Raja (2001), those who have more opportunities to adapt themselves to the environment, by changing clothes or posture, or adapt the environment to their own requirements, by using controls, will be less likely to suffer discomfort. That is why it is recommended to provide adaptive opportunities by user friendly building controls, along with visual access to outdoor climatic conditions (Baker and Standeven, 1996).

But researchers have indicated that the conventional comfort model, which is developed from comfort chamber research, is seriously flawed, as a much wider range of temperatures are found comfortable in adaptive models (Lovins, 1992). If ASHRAE design standards are based on this model, resulting systems may not assure optimal comfort, and energy will be unnecessarily wasted in the process. Other researchers have argued about the difficulties in reconciling results of comfort studies (comfort temperature), that varying research methods (Brager, and de Dear, 1998; Humphreys, 1978; Humphreys, and Nicol, 1998). Whereas, comfort research undertaken in ‘comfort chambers’, show fairly consistent and similar temperature preferences, even across cultures, with highly variable climates. Studies of comfort ‘in the field’ reveal much more variation, especially in the case of occupants of naturally ventilated buildings. The conflicting findings of comfort chamber and field studies, suggest that comfort is context-dependent or situational (Shahjahan, 2012). In light of the above, this research will also try to identify the adaptive measures that patient’s undertake, to cope with their thermal discomfort, to have a better understanding of the study context, as well as to identify ‘neutral conditions’ for the indoor thermal environment

2.1.6 ASHRAE Standards for thermal comfort:

In ‘Thermal Environmental Conditions for Human Occupancy’, ASHRAE’s Standard 55-2004 (2004) describes the combinations of indoor space conditions and personal factors necessary to provide comfort, which includes the interactions between temperature, thermal radiation, humidity, air speed, personal activity level, and clothing (Bradshaw, 2006). Table 2.7 shows the comfort chart suggested by ASHRAE, for winter heating and summer cooling design temperatures, in various types of spaces, after the observations of healthy, clothed and sedentary subjects in very active spaces (Bradshaw, 2006). It is, therefore, logical that people, who have different physical conditions, clothing styles etc. (as in Bangladesh), will require different conditions for comfort, than those suggested by ASHRAE.

Table 2.7: Guidelines room air temperatures (ASHRAE Standards 55-2004, 2004)

Type of Space	°C Summer	°C Winter
Residences, apartments, hotel and motel guest rooms, convalescent homes, offices, conference rooms, classrooms, courtrooms, and hospital patient rooms	23–26	20–22
Theaters, auditoriums, churches, chapels, synagogues, assembly halls, lobbies, and lounges	24–27	21–22
Restaurants, cafeterias, and bars	22–26	20–21
School dining and lunch rooms	24–26	18–21
Ballrooms and dance halls	21–22	18–21
Retail shops and supermarkets	23–27	18–20
Medical operating rooms[a]	20–24	20–24
Medical delivery rooms[a]	21–24	21–24
Medical recovery rooms and nursery units	24	24
Medical intensive care rooms[a]	22–26	22–26
Special medical care nursery units[a]	24–27	24–27
Kitchens and laundries	24–27	18–20
Toilet rooms, service rooms, and corridors	27	20
Bathrooms and shower areas	24–27	21–24
Steam baths	43	43
Warm air baths	49	49
Gymnasiums and exercise rooms	20–22	13–18
Swimming pools	24	24
Locker rooms	24–27	18–20
Children's play rooms	24–26	16–18
Factories and industrial shops	27–29	18–20
Machinery spaces, foundries, boiler shops, and garages	—	10–16
Industrial paint shops	—	24–27

[a] Variable temperature range required with individual room control.

2.1.7 Previous indoor thermal comfort studies in tropics

Table 2.8 presents a summary of findings chronologically since 1960 from previous thermal comfort research conducted in tropical countries (Singapore, Indonesia, Bangladesh, Thailand, Malaysia, India etc.) in the past 50 years. The shaded rows indicate studies undertaken in Bangladesh.

Table 2.8: Thermal comfort researches in tropical climate (Shahjahan, 2012)

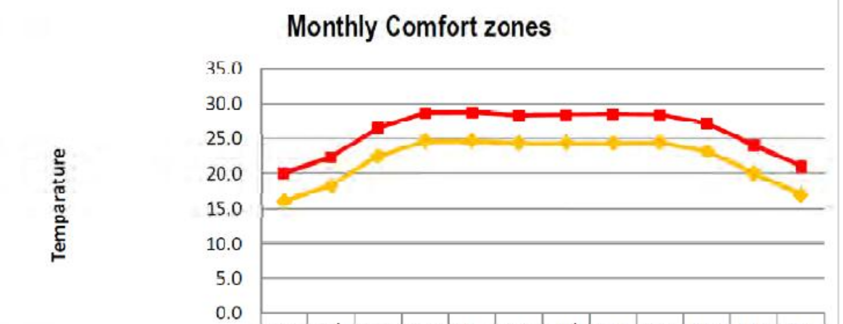
Year	Researcher	Location	Type of Building	Type of study	Temperature of comfort
1952	Ellis	Singapore, Hongkong	NV	Field Study	26.1 ET*
1950	Webb	Singapore	NV	Field Study	26.2 ET*
1986	Sharma, M.R. and Ali, S.	India (Roorkee)	NV	Field Study	21^0-30^0
1987	Ahmed, Z. N.	Bangladesh (Dhaka)	NV (Residence)	Field Study	23.1^0 C-28.6^0C
1991	De Dear,R., Foo and Leow,K.G	Singapore	NV	Field Study	Thermal neutrality (comfort) at 28.5^0C (OT)

1992	Busch, J.F.	Thailand (Bangkok)	NV, AC (Office)	Field Study	Neutral temperature was found at 28.50 ET*, ASHRAE 55-81, was 31^0 C (ET).
1994	Mallick, F.H	Bangladesh (Dhaka)	NV (Housing)	Field Study	24^0-32^0 C with no air movement
1994	Karyono, T.H	Indonesia (Jakarta)	NV, AC	Field Study	26.7 T_o
1998	Allison Kwok	Hawaii	NV, AC (School)	Field Study	Thermal comfort survey, investigation of thermal neutrality and preference.
1996-1999	Nicol, F et.al, Nicol, F., Roaf,S.	Pakistan (Five cities)	NV , AC	Field Study	Relate indoor comfort to outdoor climate.
1999	Khedari, J et.al	Thailand (Bangkok)	NV	Field Study	Proposing ventilation comfort chart
2001	Wong, N.H and Kho, S.S	Singapore	NV (Classroom)	Field Study	28.8^0 C (T_o)
2002	Wong, N.H et.al	Singapore	NV (Public Housing)	Field Study	Bedford scale compared to ASHRAE scale
2003-2004	Yau YH et al	Malaysia	AC (Hospital)	Field Study	Comfort temperature range was 25.3–28.2°C (for 90% users). Neutral temperature was 26.4°C.
2004	Feriadi and Wong	Jakarta, Indonesia	NV (Residence)	Field Study	29.2 (T_o) Neutral 26.0 (T_o) Prefer.
2004	ASHRAE Standard 55- 2004	Singapore	NV	Field Study	23.30^0-30.20^0 (80% acceptability)
2005	Hwang et al	Taiwan	AC (Hospital)	Field Study	Neutral temperature and preferred temperature were 22.9 and 23.9 1C ET in winter, and 24.0 and 24.6 1C ET in summer.
2010	Indraganti, M	Hyderabad, India	NV (Apartments)	Field Study	29.23 (T_o) neutral Comfort range: 26^0-32.45^0C
2010	M.K. Singh et al.	Tezpur, India	NV (Vernacular buildings)	Field Study	27.1^0C (T_o) neutral Comfort range (summer): NA-29.1^0C
2010	Y.Zhang et al.	China	NV (Residence)	Field Study	25.4^0C (T_o) Neutral Comfort range 22.10^0-28.7^0 (80% acceptability)
2012	Shahjahan, A.	Bangladesh (Dhaka)	NV (Rural Houses)	Field Study	Neutral temperature 31.5 °C (with no air movement) and comfort range is 29 °C to 34 °C
2012	Fatemi, N.	Bangladesh (Dhaka)	NV (RMG)	Field Study	28.5-33°C (Depending on Season)
2014	Tariq T.	Bangladesh (Dhaka)	NV (Classroom)	Field Study	Neutral Temperature 30.2°C (with no air movement) Comfort range is 29.89-30.54°C

The findings of the above studies clearly show that comfort temperatures are relatively much higher in these tropical climates then indicated by studies in Europe and North America. Many studies also highlighted that the high energy consumption due to thermal discomfort can be considerably reduced if the buildings are properly designed.

2.1.8 Thermal comfort studies in Bangladesh

Although numerous thermal comfort studies have been conducted on naturally ventilated buildings of various tropical countries since 1960, only a handful studies were done on naturally ventilated buildings of Bangladesh. In 1987, Ahmed (Ahmed, 1987) first proposed, the adaptation of Humphreys and Nicol's (1970) 'neutral' temperature model, to predict the comfort zone, in the climatic context of Bangladesh (Fig- 2.8). It was later found to be a better fit for the local context of Dhaka division than the PMV-PPD index.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lower Comfort Limit	16.0	18.2	22.4	24.6	24.6	24.3	24.3	24.3	24.4	23.1	20.0	16.9
Upper Comfort Limit	20.0	22.2	26.4	28.6	28.7	28.3	28.4	28.5	28.4	27.1	24.0	20.9

Figure 2.8: Monthly comfort zones for urban areas of Dhaka, Bangladesh (Ahmed Z. N.,1987)

Later in 1994, Mallick (1994) identified comfort conditions, for a residential housing of Dhaka, by using the Bedford scale (Humphreys, and Nicol, 1970) and ASHRAE Scale (Fig-2.9). The comfort conditions were based, on values of analysis of air temperature, radiant temperature, relative humidity and air velocity. The study found that user's comfortable indoor temperature range was 24-32^{0}C with relative humidity range of 50-95%, with no air movement, if users are wearing normal clothing, and are engaged in normal household activity. But slow (up to 0.15 m/s) air movement can make difference to comfort temperature and can enable people to tolerate relatively higher humidity.

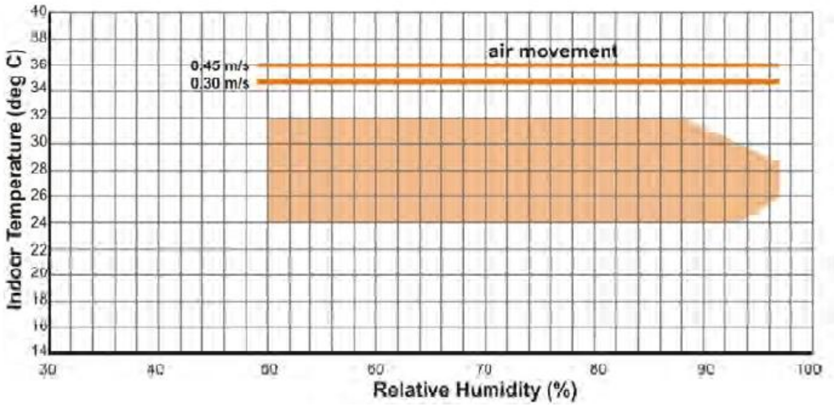
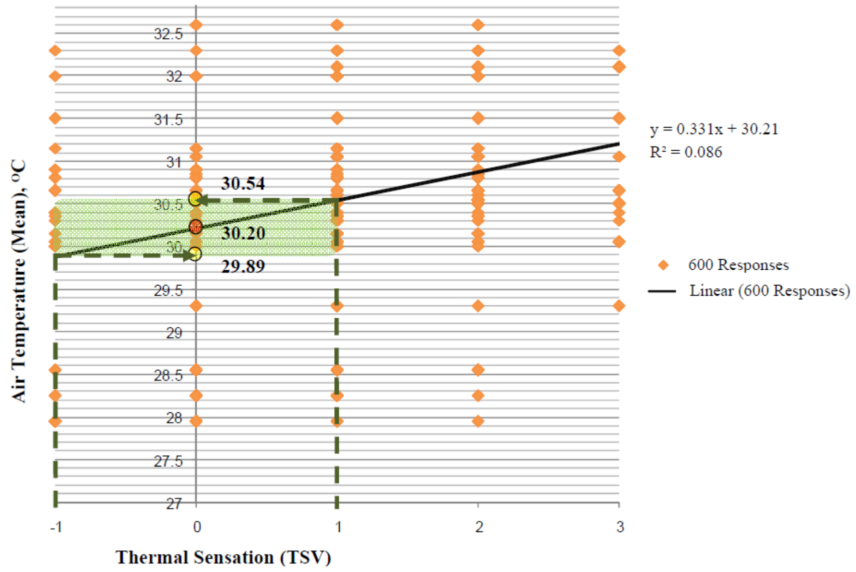


Figure 2.9: Summer comfort zone for urban housing of Dhaka, Bangladesh (Mallick, 1994)

The research showed that for slow air movement mean comfort temperature was 28.9^{0}C, whereas for higher velocities (0.3-0.45 m/s) the upper and lower limits of comfort temperature increased by 2-3^{0}C, resulting in a rise of the mean comfort temperature to 31.2^{0}C. Again for airflow of 0.3 and 0.45 m/s, the tolerance temperature can be as high as 34^{0}C and 36^{0}C respectively.

In an investigation of indoor thermal comfort in rural homes of Dhaka region, Shahjahan (2012) calculated the thermal neutrality from user's subjective responses on the ASHRAE Thermal Sensation Scale and indoor globe temperature (T_g). Later from a linear regression analysis, the researcher predicted the comfort conditions, identified the user's 'neutral' temperature at 31.5^{0}C, with a comfort range of 29-34^{0}C (with no air movement and 80% satisfaction level).

Another research was conducted in 2014 (Tariq, T., & Ahmed, Z. N., 2014), where the thermal comfort of students, in naturally ventilated class rooms of Dhaka was investigated. The authors also identified the 'neutral' and 'preferred' air temperature and relative Humidity for the students. This investigation found users' acceptable temperature range was 29.89-30.54^{0}C whereas 'Neutral' temperature was 30.2^{0}C (Fig. 2.10), and 'Preferred' temperature was 30.14^{0}C. Similarly, acceptable Relative humidity range was 65-68% whereas 'Neutral' relative humidity was 66.5% and 'Preferred' relative humidity was 57%. 57% of the users voted the indoor environment in these classrooms were 'not acceptable' while 65% voted to their unacceptability that, in addition these conditions also interfering with their class performance.



Measured environmental variable during voting	Range
Range of Mean indoor AT (°C)	27.95-32.6

Figure 2.10: Identification of 'neutral' temperature (Tariq, T., & Ahmed, Z. N., 2014)

A discussion of these previous thermal comfort studies conducted in the context of Bangladesh have helped the author to formulate an appropriate methodology or guideline, to conduct this particular research, to investigate the thermal comfort for the occupants(patients) within hospital wards..

2.1.9 Types of Analysis:

The following types of analysis were used in related earlier studies, to establish relationship between measured environmental variables and related surveyed votes, and to identify the comfort range of occupants, as well as to identify neutral and preferred environmental variables (air temperature, relative humidity and air velocity) from the results.

2.1.9.1 Correlation analysis:

The Spearman's correlation, is a nonparametric measure of the strength and direction of association, that exists between two ordinal variables, measured on at least an ordinal scale. (Spearman's Rank-Order Correlation, 2013)

Correlation analysis among respondent's votes, and the corresponding environmental variables, indicates the strength of relationship between them. Linear association, between two variables, is indicated by a value, ranging from -1 to +1, whereas the sign (- ve or + ve) of the coefficient indicates the direction of the relationship. The absolute value indicates the strength of the relationship, and the larger the absolute value, the stronger is their relationship. The '+' sign indicates a positive (Proportional) relationship between the two variables whereas '-' indicates a negative (inverse) relationship.

The level of significance is used to justify whether a claim is statistically significant or not. A significance value (2-tailed) of less than or equal to 0.05, indicates a strategically significant correlations between two variables. That means, increases or decreases in one variable do significantly relate to increases or decreases in the second variable. If the Sig (2-Tailed) value is greater than 0.05, it means that there is no statistically significant correlation between these two variables. That means, increases or decreases in one variable do not significantly relate to increases or decreases in the second variable. (Source - http://statistics-help-for-students.com, 2008)

2.1.9.2 Linear regression analysis:

Linear regression analysis, is used to relate a dependent variable (or sometimes, the outcome variable), with an independent variable (or sometimes, the predictor variable). (Linear regression analysis, 2013)

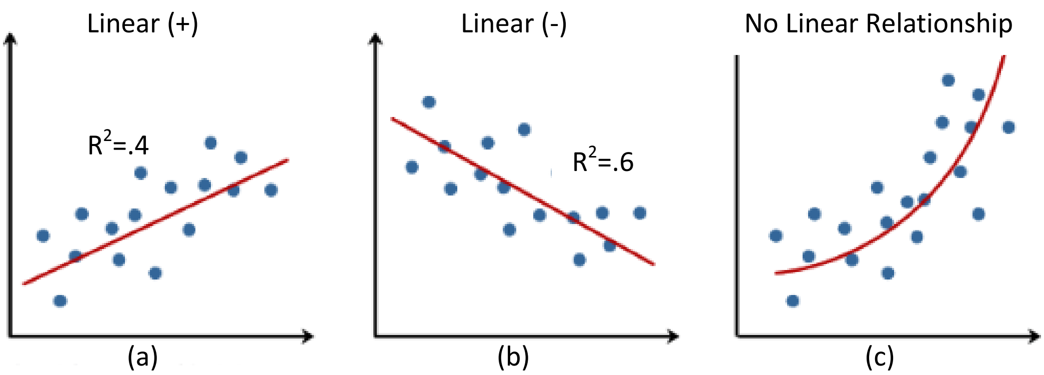


Figure 2.11: Visual representation of possible scatter plot diagram

(Source-Linear regression analysis, 2013)

To check whether a linear relationship exists between two variables, a scatterplot can be used, where dependent variables are plotted against independent variables. Through a visual inspection of the scatterplot the linearity can be checked. The scatterplot may look something like one of the above (Fig 2.11).

If the line in the graph slopes upward, it indicates a positive correlation between the variables (Fig 2.11, a). Increases or decrease in one variable are correlated with increases or decreases in the other variable simultaneously. If the line in the graph gradually slopes downward, it indicates a negative correlation between the variables (Fig 2.11, b). Increases in one variable are correlated with decreases in the other variable. If the line in the graph does not create slop, or a line cannot be imagined at all, it can be concluded as there is a zero correlation between the variables (Fig 2.11, c). That means that the variables are not related to one another. Increases or decreases in one variable have no effect on increases or decreases in your second variable. (Source - http://statistics-help-for-students.com, 2008)

The value of R^2 indicates the strength of relationships among variables, which can be between ‘0’ and ‘1’. The higher values indicate a better fit, while a value of ‘1’ indicates a perfect fit.

2.1.10 Summary

This chapter mainly focused on establishing an appropriate definition of thermal comfort, its importance on overall indoor comfort perception and wellbeing of users. It also discussed the theories regarding different approaches of indoor thermal comfort studies. This literature review helped to identify major variables that affect thermal comfort and that of those air temperature, relative humidity and air velocity play the major role, which are required to be investigated in this research. Moreover, various established measurement techniques (thermal comfort indices) of measuring the dependent variables have been discussed here in depth. All these reviews helped the author to determine most appropriate and effective guidelines to conduct this research thoroughly. The climatic section of the research area will be discussed in the next section of this chapter.

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CHAPTER 2: SECTION-B
CLIMATE OF DHAKA

2.2.1 General Overview

According to UNESCO's ecological region (Leon 1990) Bangladesh lies between 20^{0}34' N to 26^{0}33' N and 88^{0}01'E to 92^{0}41'E. Bangladesh is a low lying plain land in the Indo-Malayan realm except for the hilly region in the South-East, which is bounded by land mass on three sides and by Bay of Bengal on the South. According to Atkinson's classification of tropical climates, Bangladesh lies in the composite or monsoon climatic zone, located on land masses near the tropic of Cancer and Capricorn (Ahmed 1994). Again, according to Mallick (1994), the climate of the country is hot and humid for a major part of the year, and is generally representative of tropical climates. Generally the climate has a long and wet summer, while winter is short and dry. Due to the Himalayan mountain range and Tibet Plateau at the north, a significant amount of rainfall is observed. (Hossain & Nooruddin 1993) (Rashid 1991) As a result, humidity is fairly high throughout the year and it is often over 80% from June to September. Meteorologically, the climate of Bangladesh is categorized into four distinct seasons: Pre-monsoon, Monsoon, Post-Monsoon and winter (Ahmed 1995). Here, pre-monsoon is hot and dry, monsoon and post-monsoon periods are hot and wet whereas winter is cool and dry (Ahmed 1995) (Hossain & Nooruddin 1993) (Mridha 2002).

2.2.2 Climate of Dhaka City:

There are significant differences between the urban built up areas and its surrounding rural areas (Givoni, 1989) (WMO, 1974) (Koenigsberger et al., 1975). Similarly, the climatic characteristics of Dhaka city differ from its surrounding rural areas and other cities. Physical development, difference in surface qualities, density, heights (three dimensional objects) and other related factors are mainly responsible for this difference. The climate of Dhaka is characterized by high temperatures, high humidity, heavy rainfall and marked seasonal variations.

Although climate is a composite effect of a number of factors (Sarma 2002), air

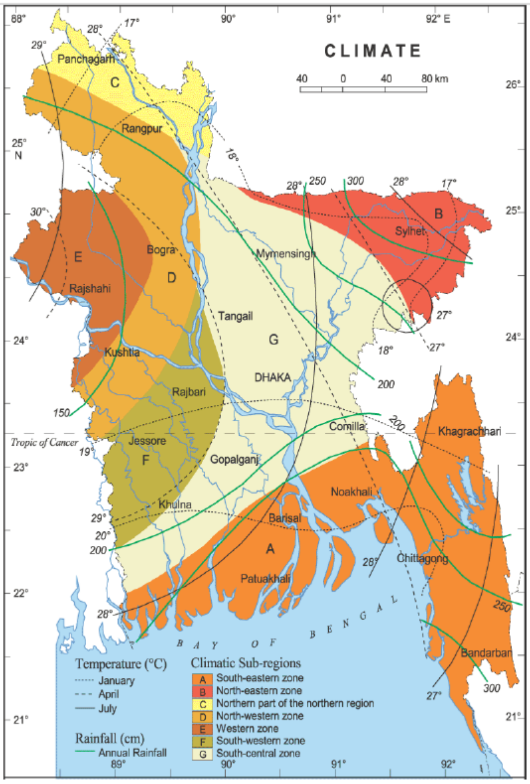

Figure 2.12: The climatic subzones of Dhaka (Source-http://www.worldatlas.com/aatlas/world.htm)

temperature, Humidity and air movement were identified as the 3 key components that drive the climate by Markus and Morris (1980). Moreover, these are the variable identified in section A that mostly influence the sensation of thermal comfort. A review of these climatic factors based on the data found from meteorological source of Dhaka region is described below.

2.2.2.1 Air Temperature:

From the temperature trends for the last 60 years, an increase of average temperature can be identified as a result of increasing maximum and minimum temperature. Fig 2.13 and fig 2.14 indicate that, the rising of maximum and minimum temperature has followed a rising trend.

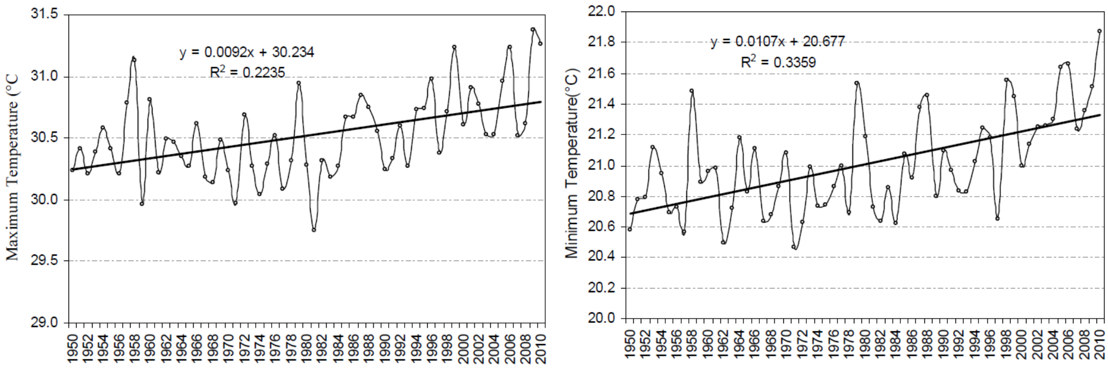

Figure 2.13 & 2.14: Temporal variation of annual maximum and minimum temperature of Bangladesh during 1950-2010

(Source: Climate division, Bangladesh Meteorological Department, Agargaon, Dhaka, 2011)

The meteorological data recorded higher monthly maximum average temperature in March (32.6^0), April (34.5^0) and May (33^0) i.e. the pre-monsoon period. In the next decade (1981-1990) slight fluctuation of temperature was seen. (After BMD 2002, Mridha 2002) According to Roy (2010), due to clear sky, dry weather, higher solar altitude angle, higher solar intensity and higher duration of sun-shine hour, April is considered to be the hottest month of the year in this region. In general, the pre-monsoon period shows the highest annual temperatures in April.

From the Appendix-02, it can be seen that June has the highest temperature during the monsoon period. Although the average temperature during this period was following a rising trend from 1950 (28.6^{0}C) to 2000 (29.5^{0}C) but during 2002-2006 it has decreased to some extent. In general, the average temperature during this season remains steady but when it is coupled with high humidity values, it creates adverse thermal environment. BMD data shows a constant increasing of the annual average temperature with the last four decades, which is consistent with the regional data of Bangladesh. (Fig 2.15)

Even though the dry season displays the highest temperature, it is clear that, when looking at the combination of relative humidity with air temperature, the effect on human, during the large warm humid season, used for investigation.

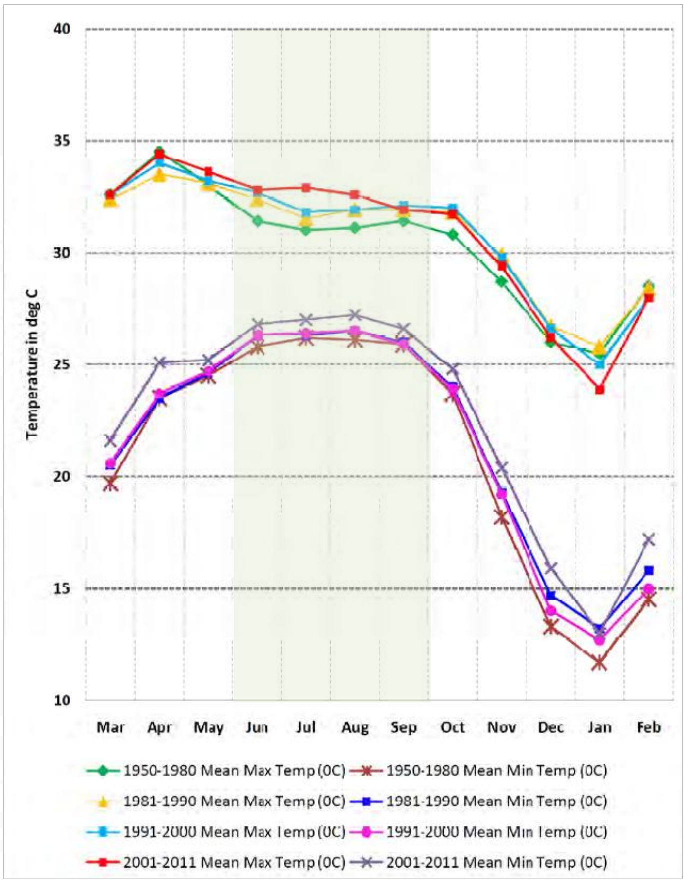

Figure 2.15: Monthly Mean Maximum and Minimum air temperature profile for the year 1950-1980, 1981-1990, 1991-2000, and 2001-2011 (Shahjahan, 2012)

2.2.2.2 Relative Humidity:

Compared to adjacent rural areas the relative humidity of Dhaka city is lower and it generally decreases towards the city center. (Hossain and Nooruddin 1993, Mridha 2002) In addition, relative humidity is inversely related with prevailing temperature. Thus, in any given situation, increasing temperature will reduce the relative humidity levels, other conditions remain same (Mridha 2002). Another study found that urban community near the surface decrease due to 50% impervious covers and rapid run off. Run off increases by 200% compared to rural areas. (Ahmed, 1994)

From the data provided by the meteorological office of Dhaka showed that the relative humidity is highest in the monsoon and comparatively low in the winter seasons. The mean annual relative humidity between years 1950 to 1980 was 76%. But data of recent years (2001-20111) exhibited that the average range of relative humidity is 81-82% during monsoon period and highest monthly mean value is 82% in August. Fig-2.16 exhibits a decreasing trend of relative humidity with time.

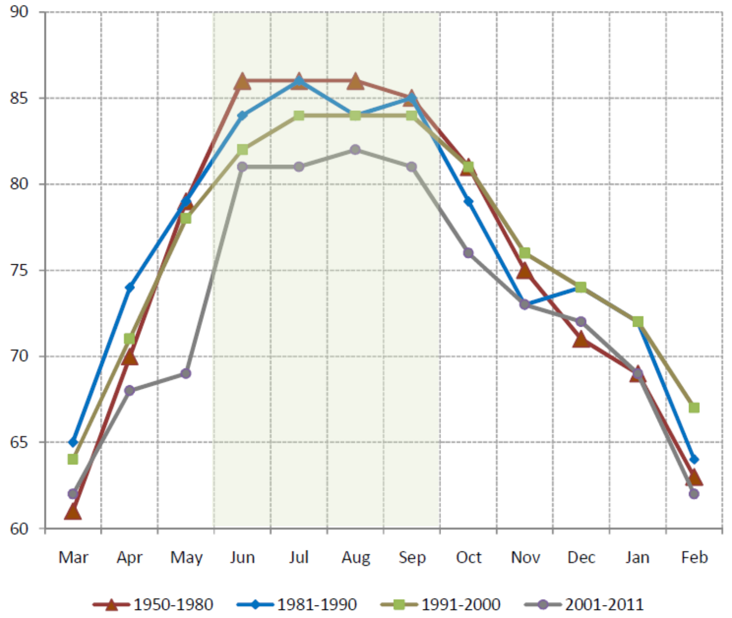

Figure 2.16: Monthly Relative Humidity and annual variation during 1950-2011 (Source: Climate division, Bangladesh Meterological Department, Agargaon, Dhaka, 2012.)

2.2.2.3 Air velocity and direction:

Airflow plays an important role in thermal comfort during warm-humid (monsoon) period, when the humidity range is high. Table 2.9 shows the meteorological data from 2002 to 2006, which was measured in open locations of Dhaka. It can be seen that prevailing wind speed in Dhaka is comparatively high in warm humid period (pre-monsoon and monsoon). Highest and lowest recorded wind speed during the monsoon period was 4.7 m/s and 3.5 which were measured in September and June respectively. Prevailing wind direction is South-Easterly during monsoon period (June-September).

Table 2.9: Monthly mean prevailing air velocity and direction of Dhaka city for 1950-1980, 1981-1990 and 2002-2006 (Rashid, 2008)

	Pre-Monsoon			Monsoon			Post-mon			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Mean wind speed for 1950-1980 (m/s)	2.8	2.8	3.9	3.3	4.2	3.9	3.1	1.7	1.4	1.9	1.4	1.7
Mean wind speed for 1981-1990 (m/s)	2.4	2.9	2.4	2.3	2.2	2.2	2.1	2.1	1.3	1.6	1.4	1.9
Mean wind speed for 2002-2006 (m/s)	4.5	4.7	4.4	3.4	3.5	3.8	4.7	3.3	2.4	2.9	3.3	3.5
Prevailing wind direction	SW	SW	S	SE	SE	SE	SE	N	NW	NW	NW	N

2.2.3 Climate variable matrix:

Based on environmental variables in different seasons of the year, thermal comfort criteria are different. Table 2.10 indicates scale of impact of different environmental components for the whole year in Dhaka. (Fatemi, 2012)

Table 2.10: Environmental Matrix for Dhaka (Fatemi, 2012)

	Winter		Pre-Monsoon			Monsoon				Post-mon		Winter
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature	1	1	3	4	4	3	3	3	3	2	2	1
Relative Humidity	1	1	2	3	3	4	4	4	4	3	3	1
Air Velocity	1	1	3	3	4	4	4	3	3	2	2	1

4 3 2 1 Scale (of Impact)

From the table, it is evident that pre-monsoon period and the monsoon period are the critical parts of a year in Dhaka. While pre-monsoon period has high air temperature, with a high amount of solar radiation, the monsoon period is crucial, in terms of potential impact on occupant's thermal comfort, due to high relative humidity level, along with high temperatures. This validates the purpose of doing this research during warm humid period, which is often the most lasting environmental condition of Dhaka.

Table 2.11 presents the mean data of all relevant thermal comfort variables of the current weather of Dhaka which will be the base condition for the data analysis of this research that will be described in the following chapter.

Table 2.11: Weather condition of Dhaka region according to classification of the seasons for 2012 (Source: Climate division, Bangladesh Meteorological Department, Agargaon, Dhaka, 2012)

Months	Meteorological Seasons	Avg. air temperature (Mean) (^{0}C)	Mean Relative Humidity (%)	Mean Rainfall (mm)	Mean Air velocity and direction (m/s)
March	Pre-Monsoon (Hot Dry)	28.2	64.6	120.4	3.4 (SW)
April					2.9 (SW)
May					6.4 (S)
June	Monsoon (Warm-Humid)	29.1	82.3	371	2.3 (SE)
July					2.2 (SE)
August					2.2 (SE)
September					2.1 (SE)
October	Post- Monsoon (Warm- Humid)	25.9	75.7	107.9	2.1 (N)
November					1.3 (NW)
December	Winter (Cold-Dry)	18.9	67	13	1.6 (NW)
January					1.4 (NW)
February					1.9 (N)

2.2.4 Summary:

This section has presented an analysis of the climatic situation of Dhaka city along with the understanding about its potential future impacts on this region. The findings will help the author to select the appropriate critical period for thermal assessment of the in- patient hospital wards in Dhaka.

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CHAPTER 2: SECTION-C

HEALTHCARE ARCHITECTURE PRACTICES AND THERMAL COMFORT RESEARCH ON IN-PATIENT WARDS

2.3.0 Introduction

Similar to other building types, Healthcare architecture especially the design of hospital buildings, has also gone through evolution over time. By considering the problems of earlier designs and medical advancements, new designs were developed to address them, and to meet up occupants' requirements and expectations. Due to the rapid growth of population, shortages of hospitals have been observed. To meet this growing need the Bangladesh Government has erected numerous hospitals, for the last two decades and have an agenda for building several new hospitals in future. This chapter mainly focuses on the common practice in hospital architecture, both national and International; its evolution, typology of in-patient wards, codes and standards regarding indoor thermal condition, and summary of previous research in the same context, both national and International, to justify the selection of necessity of this study in the context of Bangladesh.

2.3.1 Background

Although evidence of earlier hospitals were discovered in Egypt, Sri Lanka, India, and Greece, most of them were affiliated with religious structures like temples, monastery etc. (Zilm F.,1946) Roman military hospitals or 'valentudinaria' from around the 100s BCE are considered as the first well-documented healthcare facilities (Tom Gormley, 2010). Their form was similar to military barracks and most of them had a quadrangular plan, ranging from 150-200 feet, by 250-300 feet with a central rectangular court. The wards were arranged on both sides of the main circulation corridor, and were extended continuously, through all four sides of the building. The Roman Military hospital of Vindonissa (in present day Switzerland) (Fig 2.17), which was built in the 1st century AD, is one of the best examples (Tom Gormley, 2010).

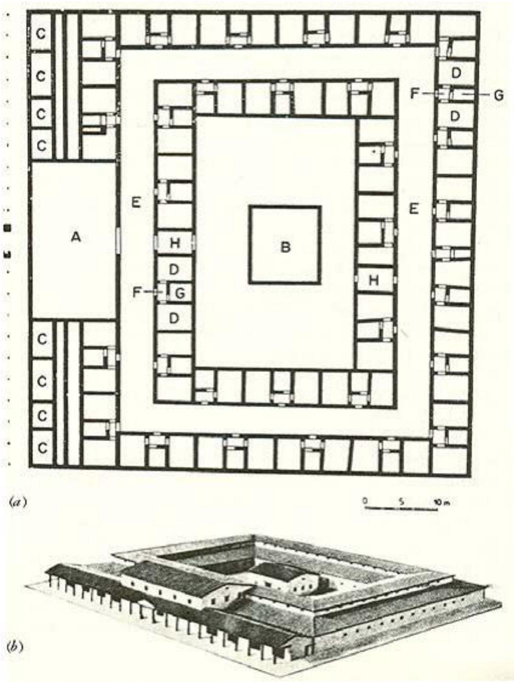

Figure 2.17: Roman Military hospital in Vindonissa (present Switzerland).Source- http://image.wikifoundry.com/image/3/AA0sPOIGE0h8Nff2hEIlZA304384/GW434H5

From the 600 AD hospitals were made available to the poor, by constructing large open wards in religious institutions or churches (Tom Gormley, 2010). The religious influence can be observed in the cruciform plan (Fig 2.18 & 2.19) in the 1400s (Tom Gormley, 2010). The large patient wards were arranged in the four segments of the cruciform, so that each patient could have a view of the central altar (Rosenfield, I., & Rosenfield, Z.,1969). Subsidiary rooms, that contained the service facilities, treatment and administration were placed at the periphery of the square, and colonnaded porticoes served as the connection between different wards and other facilities (Rosenfield, I., & Rosenfield, Z.,1969). Multiple patients were often placed in wards, which became the standard for the public hospitals for hundreds of years. Even many current hospitals are still continuing this practice, but instead of the altar at the center are replaced with the nurse's station (Tom Gormley (2010).

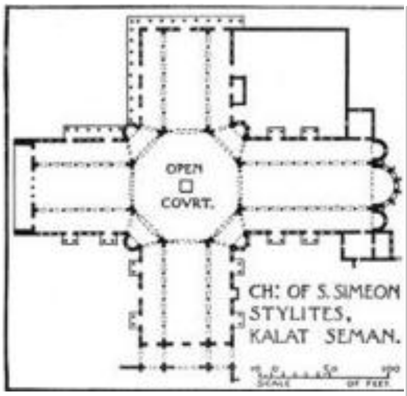

Figure 2.18: The Church of St. Simeon Stylites in Syria (5th Century CE)

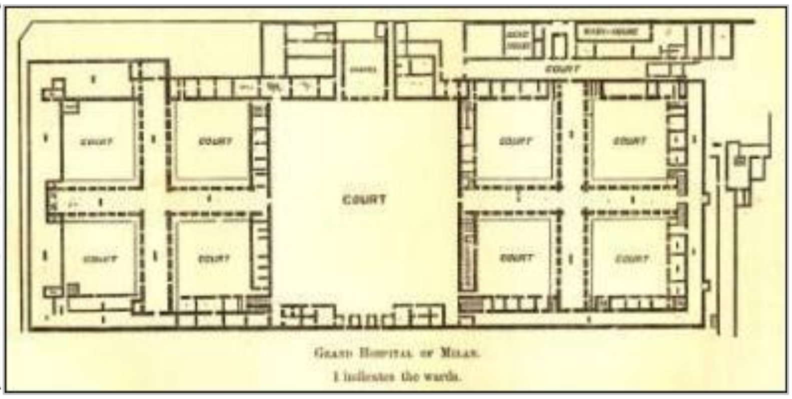

Figure 2.19: The Osepedale Maggiore in Milan Italy (ca 1500 CE) (Zilm F.,1946)

Distinct development of healthcare facilities can be observed in the Renaissance period and one of the best known examples was Hotel Dieu in Paris (Fig 2.20). (Zilm F.,1946) Due to increased numbers of patients, the wards became larger and the pressure on them produced dangerous conditions by the mid-1700. It often housed more than 3500 patients which resulted in over 100 beds in some wards and up to 6 patients per bed. (Zilm F.,1946) The wards were dark, poorly ventilated, unsanitary, and often located adjacent to other wards with infectious patients (Tom Gormley, 2010). To solve this problem and to ensure a pure, natural environment two architectural proposals were made: a radial solution and a pavilion system (Burpee, 2008). The new “pavilion” plan was first implemented at Hospital Lariboisiere, built between 1839 and 1854 in Paris.(Burpee, 2008).

Figure 2.20: Hotel Dieu in Paris

During Crimean war of the 1850s, Florence Nightingale witnessed a mortality rate of more than 40% of the patients in the military barrack hospitals in Istanbul due to horrible, dirty and unsanitary conditions. Upon returning to England, she gave major recommendations to improve the conditions of pavilion type hospital design (Zilm F., 1946). These hospitals included a primary supply corridor for circulation of people and supplies with finger-shaped plan for patient wards that extend off of this linear spine. The thin pavilion plan allowed light and fresh air to penetrate inside and created garden views between the building crenellations. This design emphasized function over form (Burpee, 2008). This plan retained the multiple patient ward approach, which was also known as the Nightingale Ward shown in Fig 2.21 (Tom Gormley, 2010). The pavilion model, as well as the nightingale ward, became a dominant architectural feature for major hospitals during the 1920s, which continues until the mid-1960s. Many variations of the layout of the nursing units of pavilion type hospitals were developed over time. Such as the Y-shape design, the cruciform, circular units, hubs with interconnected links etc. (Zilm F., 1946)

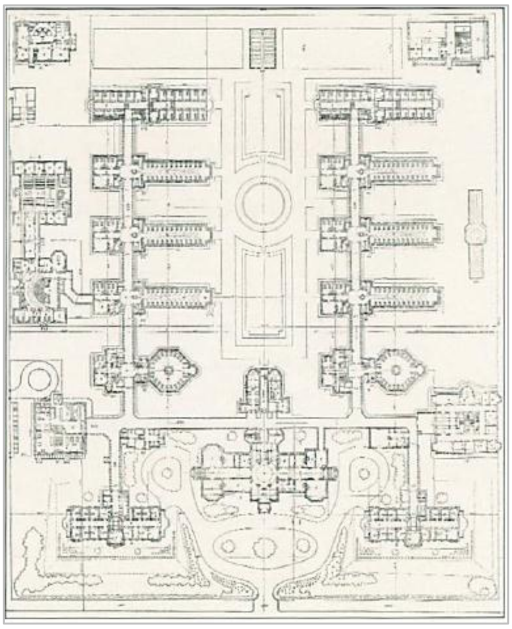

Figure 2.21: Johns Hopkins in Baltimore

With the advancement of technology, the invention of elevators, integration of mechanical heating and ventilation system etc. made it possible to build high rise hospitals, especially in dense urban areas. (Zilm F., 1946) So apart from the pavilion style, a new typology emerged known as 'podium on a platform' typology (Fig 2.22). (Burpee, 2008). The inpatient nursing units were stacked, on a large base block of space, which housed diagnostic, treatment and other support services. Generally, the nursing towers defined the structural and circulation systems of the lower spaces. Various building shapes, such as- rectangular, Y-shaped, circular or triangular geometries were generated to fulfill the requirements of outside windows for daylight and ventilation in the inpatient units (Zilm F., 1946).

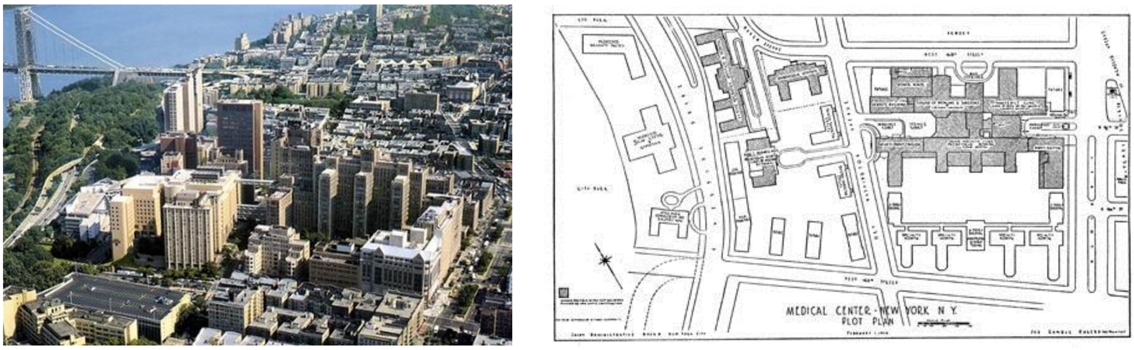

Figure 2.22: Columbia Presbyterian Medical Center, New York

Deep span frame structure, and the provision of mechanically ventilated interior spaces, gave architects the opportunity to plan large hospital buildings, in one continuous floor which created a mechanized place of healthcare. These were known as 'mega hospitals' (Burpee, 2008). With the progression of medical and diagnostic technology, the podium was growing larger, which limited the access of natural air and light. The designs of hospitals were becoming more machine like, which was efficient, but often didn't have consideration for human health, stress and comfort (Burpee, 2008). So, in the 1980's, a new research field, which oversees the role of the hospital building related to human health, healing, and comfort emerged, known as Evidence-Based Design. It helped to derive hypothesis from intuitive approaches to design, that ensures human comfort, as well as assessing the connection between natural environments and healing, that is similar to the earlier Nightingale concept.

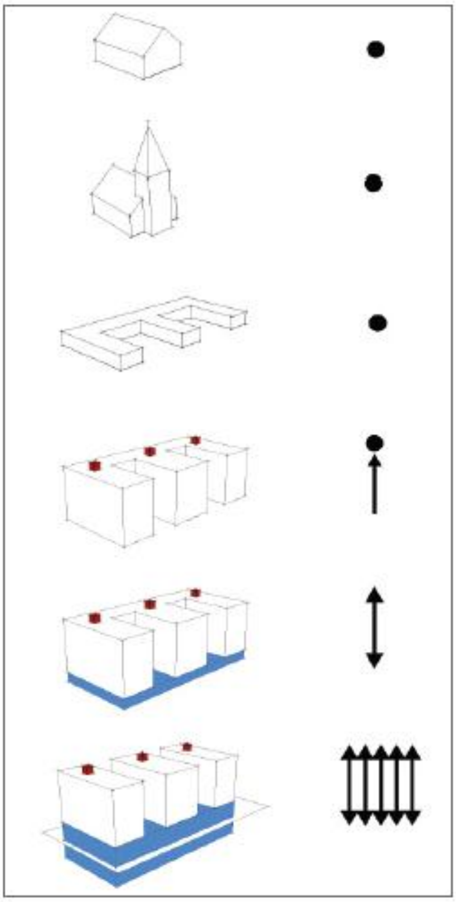

Figure 2.23: Evolution of patient care from the home to "Podium on a Platform" typology. (Burpee, 2008)

2.3.2 Hospital architecture in Bangladesh

The British government first introduced the concept of public healthcare facilities in this region during the colonial period. But the latter half of the 19th century, is considered to be the beginning of the practice of present healthcare service, as many health facilities and formal training facilities were established during that time period. After the India-Pakistan partition in 1947, epidemic diseases (malaria, small pox, cholera etc.), exploding population and poor access to healthcare service by rural population led to the establishment of rural healthcare centers. By 1971, there were about 1200 dispensaries, 120 Government hospitals, 8 medical colleges and 1 post graduate college in Bangladesh. Although the then Pakistani government already had plans for construction and expansion of sub-divisional and district hospitals, to develop and extend hospital services more, these programs were not fully executed, due to the Independence war in 1971.After independence, new healthcare policies were formulated, and a number of programs were also introduced, to improve the healthcare services. Though the new programs could not bring change in the existing situation, then a significant rise of private hospitals was seen in the city of Dhaka.

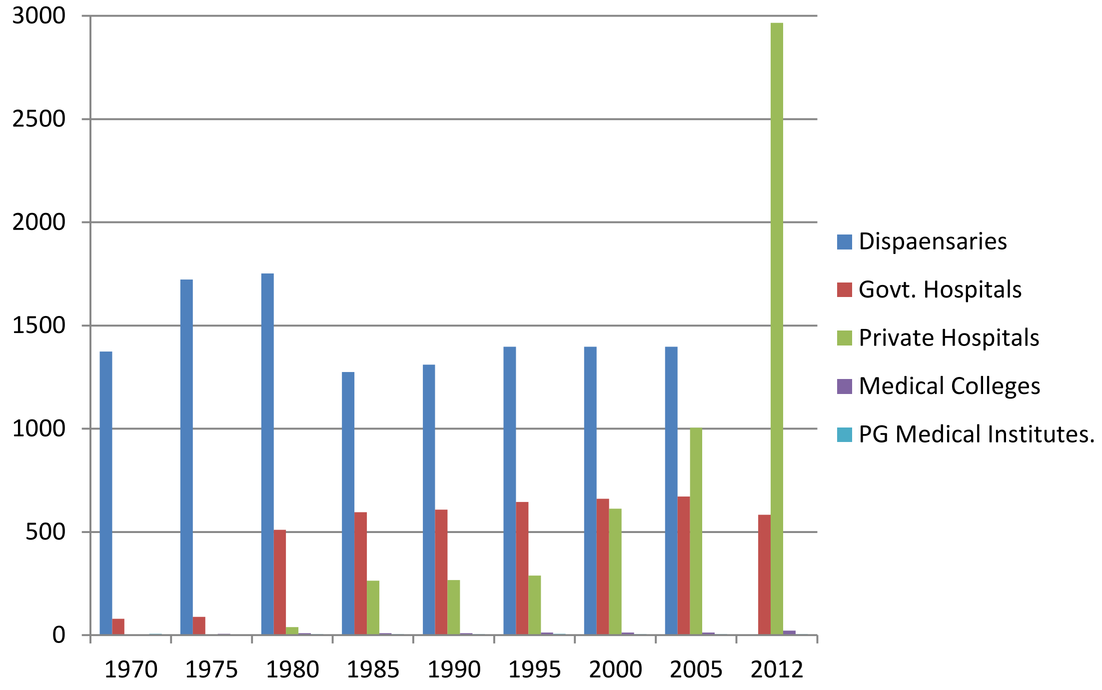

Fig 2.24: Distribution of Healthcare facilities in Bangladesh (Appendix-03)

The healthcare sector made significant improvement during the period of 1978-86. By 1986, there were about 1275 dispensaries, 600 Government hospital, 264 private hospitals, 9 medical colleges and 5 Post-graduate specialized medical institutes in the country. As the 1990's approached, the Government took several measures to expand facilities for training more physicians and specialists in the "Third five year plan", and the implementation continued. In present times, Government is committed to expand healthcare services, along with training new physicians. So, a sharp increase in establishment of specialized hospitals and medical college hospitals can be noticed after 1992.

The main practices for designing hospitals before 1990 can be found, which indicated that the hospital's layout was often evolved from the solution of the problem that was raised in the previous layouts (Hussain, 1988). Summarizations of these typologies are given below.

Detached plan layouts (Fig 2.25) were in practice in the early 20th century independent blocks of different shapes and sizes at different times, and the blocks were connected by pedestrian or vehicular roads. They followed a hierarchical order of use, and were beneficial during horizontal expansion. But due to poor connection between blocks in adverse weather conditions as well as security and privacy needs, most of these hospitals failed to meet up to local demands. (Hussain, 1988). Most of the hospitals followed the pavilion unit design or more specifically Nightingale Ward layout. This traditional layout followed an 'open ward layout' where about 20-40 patients were put in one room and under the care of one nurse station, along with their own ancillary services (Zilm F.,1946) (Llewelyn-Davies, 1966). As a result, hospitals were designed with narrow rectangular inpatient ward blocks, with double-loaded bed arrangements, with one nurse station at the end. This type of arrangement allowed proper air circulation, within the wards as well as ensured proper day lighting.

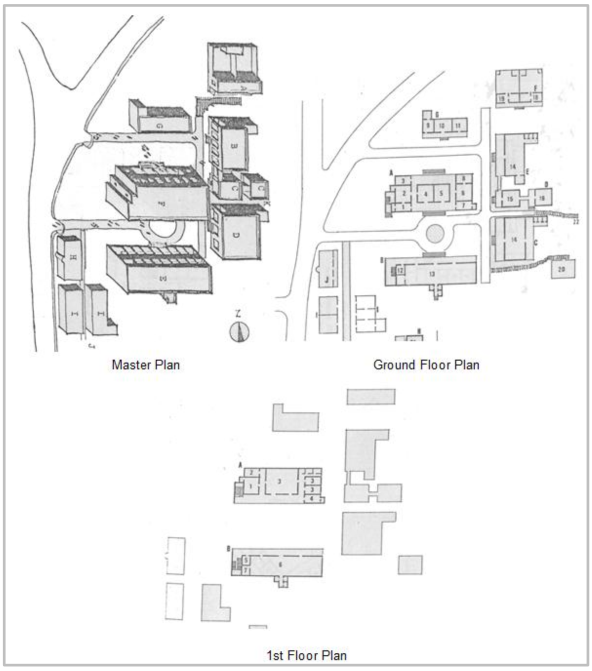

Figure 2.25: All Floor Plans of Hospital 'A' (Hussain, 1988)

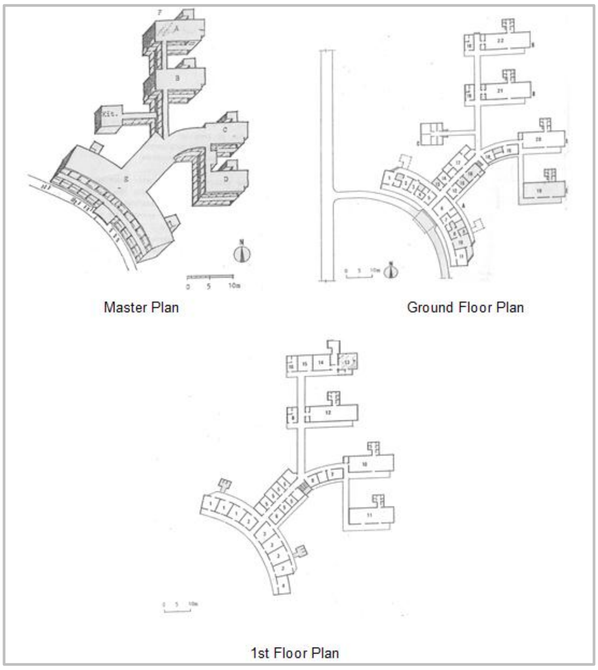

Figure 2.26: All Floor Plans of Hospital 'B' (Hussain, 1988)

After experiencing the linkage problem in earlier plans, linked pavilion blocks were used for designing new hospitals during the pre-independence periods (before 1971). These hospitals (Fig 2.26) had pavilion type inpatient wards and a large multifunctional block (outpatient, emergency, administration etc.) connected by a system of corridors. These hospitals were good for horizontal expansion as well, but enough consideration was not given for vertical circulation. (Hussain, 1988) The in-patient wards followed similar nightingale ward layouts of the previous type, which promoted cross ventilation and adequate daylighting.

To reduce the problems of long circulation paths, architects started to focus on compact layouts, during the late sixties, and thus the' linked compact block" plan came into being. These hospitals (Fig 2.27) were divided into three distinct zones (Public, Restricted and Private) for the first time in an articulate manner. The layout reduced walking distance between departments, while security and privacy of different blocks were also increased. (Hussain, 1988). The multistoried inpatient wards still followed the nightingale layout. But sometimes the classic units were subdivided into small units of 8-12 patients. These subunits shared common ancillary services, and a common nurse station. These smaller units also resolved the problems regarding privacy and comfort of patients. Air movement and daylighting remained adequate.

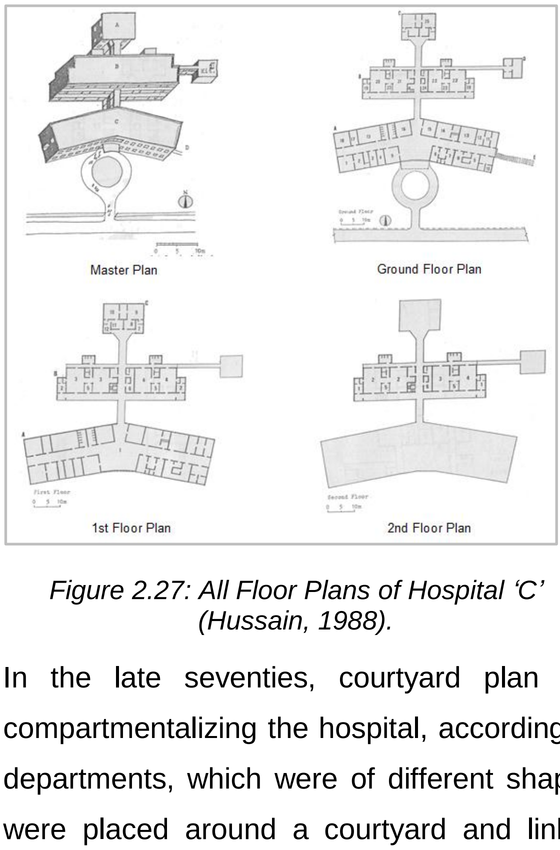

Figure 2.27: All Floor Plans of Hospital 'C' (Hussain, 1988).

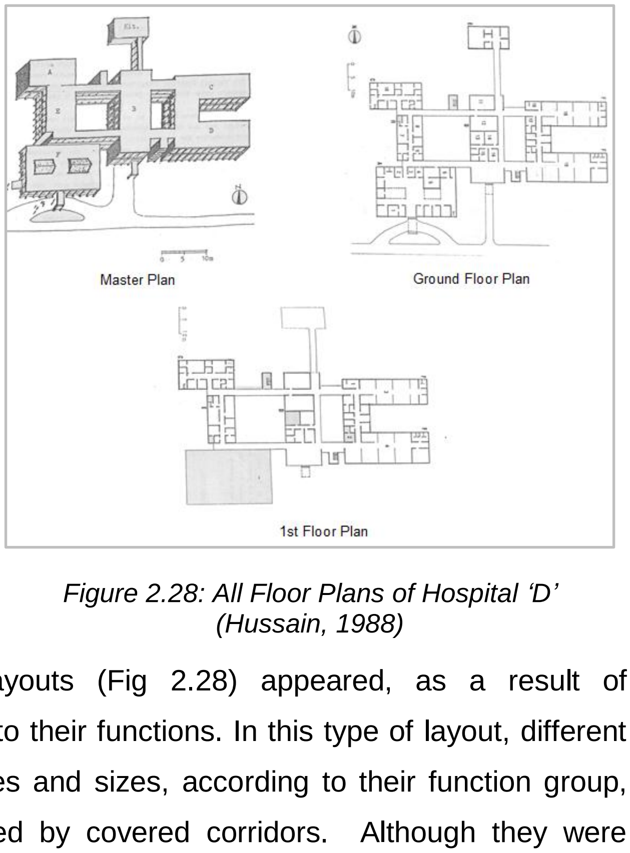

Figure 2.28: All Floor Plans of Hospital 'D' (Hussain, 1988)

In the late seventies, courtyard plan layouts (Fig 2.28) appeared, as a result of compartmentalizing the hospital, according to their functions. In this type of layout, different departments, which were of different shapes and sizes, according to their function group, were placed around a courtyard and linked by covered corridors. Although they were successful in achieving a proper hierarchical order, but the positioning of blocks was not logical, and relationships between departments was ignored, to a great extent. (Hussain,

1988) Sometimes the in-patient wards were placed around a court yard, to ensure proper lighting and ventilation between the blocks.

By this time, hospitals couldn't keep up with the increased demand in health facilities. Also, due to the improvement and development in medical technology fields, change of ward, typology, introduction of mechanically controlled rooms, and limitations in the scope for horizontal expansion, the Government's Architects realized that to meet up the future demand, required adopting new measures. In the early nineties, the 250 bed General Hospital in Narayangonj, founded by the Government of Japan and several other modern hospitals in neighboring countries (India), were carefully observed and these served as their examples. So, with the help of specialists, these Government Architects established a standard guide, for sizes of all the spaces, and necessary spatial relationship between them. In the early nineties two new hospital types were developed, by following the concept of compartmentalization, and linked compact plans, where different blocks containing different functions were clustered together, according to their functional relationship, and were organized around multiple courtyards. Covered corridors, connecting the blocks maintained smooth connections. Proper zoning and the multiple courtyard system, ensured adequate natural lighting and ventilation, in each block. Adequate consideration was given for both horizontal and vertical expansion.

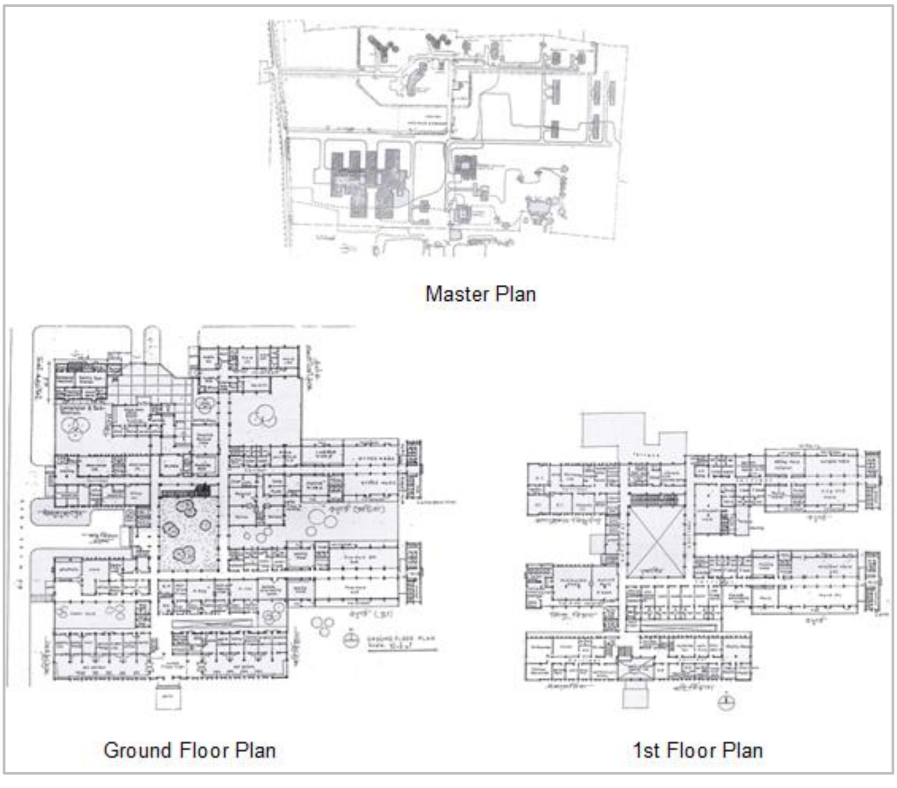

Figure 2.29: All Floor Plans of Hospital 'E' (Hussain, 1988)

Although the previously established guideline is, at present serving as a base line, for designing public hospitals, but with new development in medical fields, and with increasing demands these present, the layouts are evolving along time. From 1992, most of the hospitals (Fig 30-32), especially medical college hospitals, were following a certain prototype for construction, where the medical college hospital also acts as a district hospital, and simultaneously trains medical students. About 15 hospitals, affiliated with medical colleges, were constructed till the nineties, that followed this prototype. The plans are simple rectangular or square in plan, where different functions are arranged in blocks, around multiple smaller size courtyards, along with distinct vertical zoning. Decreased travel time, and the scope of vertical growth to meet future needs, was considered to be the positive development in this typology. However, long corridors, difficulty in horizontal expansion (department wise), and small courtyards that fail to fulfill their purpose of providing adequate natural light, ventilation etc., to the interiors were found problematic.

Due to limitations of land, and to serve the need for vertical expansion for future extensions, current hospitals, especially in urban areas, are designed in an extremely compact style. Fig 2.32 can be seen as an example for this prototype. The in-patient wards of the new hospitals were divided into small sub units of 8-12 beds per room, which made the surveillance of nursing units more effective as well as improved privacy of the patients. This type of setting wasflexible in use, can admit patients of single sex, specialty, and can also fulfill the fluctuation demands of admission. (Llewelyn-Davies, 1966)

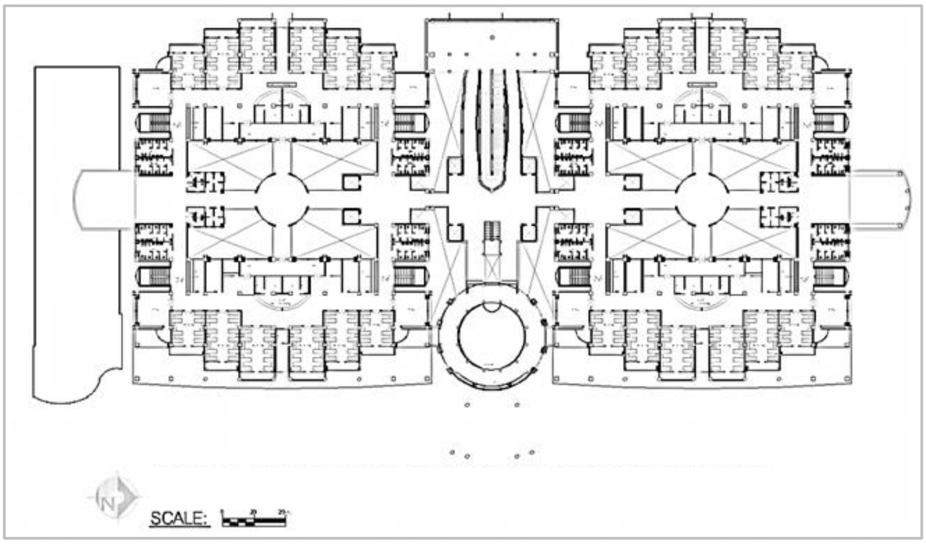

Figure 2.30: Typical floor plan Hospital 'F' (In-patient wards)
(Source- Department of Architecture, Public Works Department, Bangladesh)

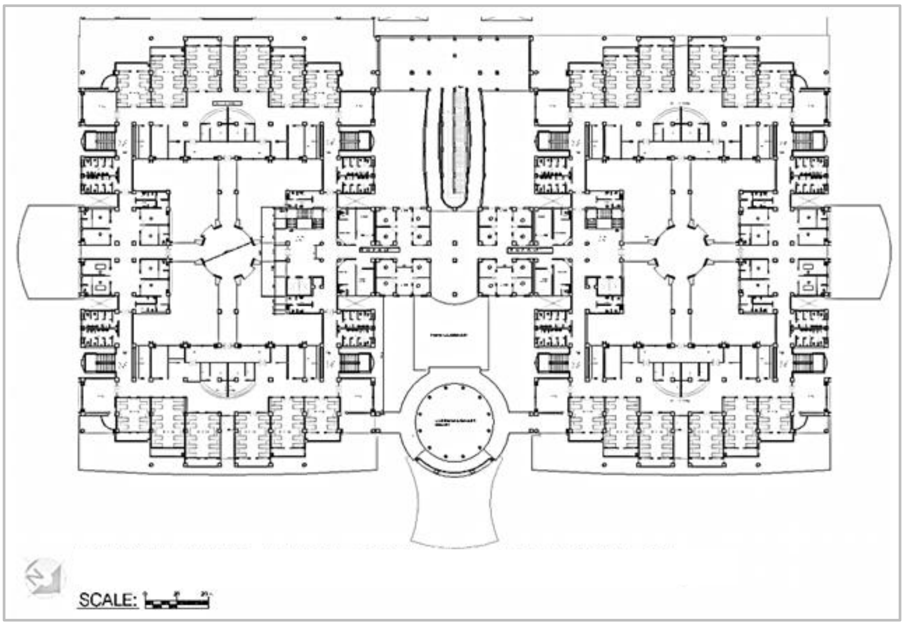

Figure 2.31: Typical floor plan Hospital 'G' (In-patient wards)

(Source- Department of Architecture, Public Works Department, Bangladesh)

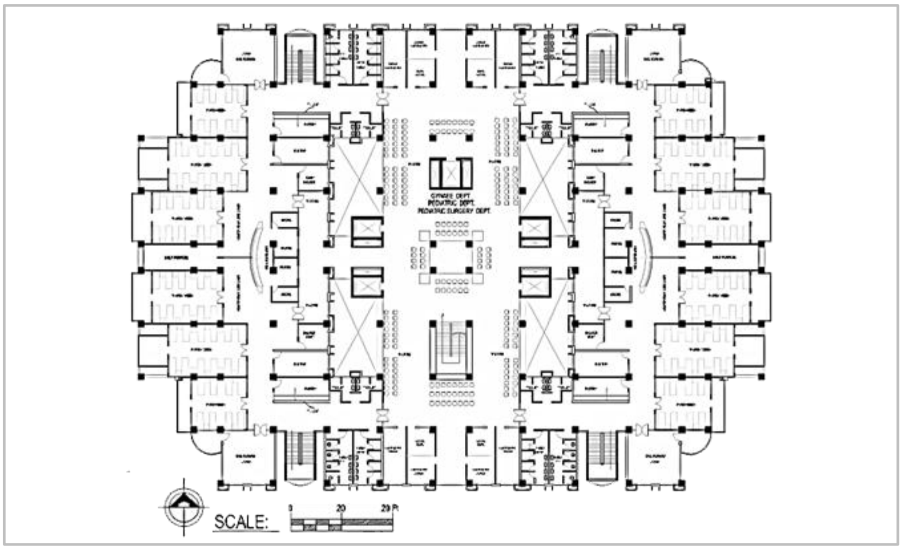

Figure 2.32: Typical floor plan Hospital H (In-patient wards)

(Source- Department of Architecture, Public Works Department, Bangladesh)

This prototype design has been used to build many hospitals, associated with medical colleges, and the Government has future plans to build more of these in future. A preliminary survey of this research has revealed that the prototype design for the hospitals is followed almost without change despite significant differences in site contexts. Limited access for cross ventilation has the potential to affect the indoor thermal condition of these hospital wards negatively. Among the proto types studied in the pre-survey, the Mugda 500 bed hospital has been chosen for this study, after following several criteria (See Chapter-3), and a representative of the worst case scenario of the proto type of Government medical college hospital. In this hospital, the wards are East-west oriented, and therefore were presumed to lack proper natural ventilation options. For a non-air conditioned hospital like this, the orientation of these in-patient wards can have an adverse effect on the indoor thermal condition, especially during the hot and warm humid periods. Therefore, it is important at this point, to investigate the actual situation of these non-air conditioned adult in-patient wards during warm humid periods, when air movement is must needed. (Ahmed, 1987)

2.3.3 Codes and Standards for thermal comfort in hospital:

a. International Standards:

The thermal comfort standards and guidelines of ASHRAE standard 55 (2007), International Society of Indoor Air Quality (ISIAQ, 2003) and VIPA (2002) regarding thermal environmental conditions of patient’s room in a hospital can be summarized as follows.

Table 2.12: Codes and Standards for thermal comfort in hospital (Verheyen, Jan, et al., 2011)

	Design Temperature [^{o}C]	**RH [%]**	**Max. Air Velocity [m/s]**	
ASHRAE; 2008	21-24	Max. 60	-	Inpatient nursing: Patient’s room
ASHRAE; 2007	21-24	30 (Winter)-50(Summer)	-	Hospital had outpatient facilities: nursing and patient room
ISIAQ; 2003	-	< 60%, preferable <50%	-	Healthcare: Patient’s room
VIPA; 2002	23.5-25.5/ 21-23	40-65	0.18/0.15	Optimal (Summer/Winter)
	23-26/20-24	30-70	0.22/0.18	Normal (Summer/Winter)
	22-27/19-25	30-70	0.25/0.21	Minimal (Summer/Winter)

b. National Standards:

Some design guidelines for comfortable air conditioning can be found in the Bangladesh National Building Code (BNBC, 2015) (Appendix-04). It may be noted that no specific standards, regarding thermal comfort of patients in non-air-conditioned in-patient wards, were found in the BNBC.

2.3.4 Previous indoor thermal comfort studies in hospital:

For the last few decades, various extensive research works have been conducted on thermal comfort requirements of patients and hospital workers in inpatient hospital wards in different regions of the World. The findings clearly reveal that these standards often vary with the climate of the specific place and their user preferences. A summary of the major research and studies are presented in table 2.13.

Table 2.13: Thermal Comfort research in In-patient wards

Year	Author	Location	Climatic Zone	Sample Size	Findings
2003-2004	Skoog *et al* (2005)	Sweden (Southern part)	Temperate	35 patients and 40 employees (One Hospital)	• Satisfaction with air temperature of **21-22°C** and relative humidity of **16-22%** • The Air temperature complied with ASHRAE standards but RH was quite low. • One possible reason was adaptability to environment through clothing levels.
2003-2004	Yau and Chew (2009)	Malaysia	Tropical Climate	4 hospitals and its 114 workers	• Comfort temperature range was **25.3–28.2°C** (for 90% users). • Neutral temperature was **26.4°C**. • 49% of the occupants were satisfied whereas only 44% of the locations met the comfort criteria specified in ASHRAE Standard 55.
2005	Hwang *et al* (2007)	Taiwan	Tropical Climate	927 patients (One Hospital)	• Neutral temperature and preferred temperature were **22.9** and **23.9 1C ET** in winter, and **24.0** and **24.6 1C ET** in summer. • 40% of thermal environment followed ASHRAE standards but 47% of humidity measurements were above standard. • Physical strength had highest influence on patient's thermal comfort but age, gender or acclimatization didn't have any significant influence.
2008-2009	Khodakarami J, Knight I, Nasrollahi N (2009)	Iran	Hot Dry Climate	14 patient rooms in four hospitals	• Patients were satisfied with indoor environment which followed Iranian thermal regulations. [Air Temperature : **24-28°C** & Relative Humidity: **30-60%**] • Rooms were out of the thermal comfort zones that were recommended by ISO7730, ASHRAE 55R and CIBSE. • Adjustments were done by the level of coverings according to user's preferences.
2011	Verheyen, Jan, et al., (2011)	Belgium	Temperate	99 patients (One hospital)	• 29% of the thermal environments were not fulfilling ASHRAE design ranges of temperature and relative humidity, but 95% of the patients accepted the environment (direct assessment).

Similar to earlier thermal comfort research studies (section 2.1.6), the researches on hospital of other tropical countries also show deviation from other climatic zones. The neutral temperature, comfort range, etc. were higher from the cooler climatic standards. Due to adaptation and acclimatization, in tropical climates (with high temperature and humidity levels), patients have a wider and higher comfort range, and often prefer warm temperatures. Expectation of the population is also found to affect thermal preferences. These issues have been discussed further in Chapter 2 Section A. So, it is necessary to conduct thermal comfort research in the context of each country.

2.3.5 Summary

This chapter briefly discusses the development of hospitals, both national and international, to understand patient's requirements or comfort in in-patient wards. In the case of Bangladesh, most of the hospitals are highly dependent on natural resources, due to limitation of artificial sources. So, indoor environments tend to change along the outdoor atmosphere and seasons. As a result, the same building doesn't produce the same set of environmental conditions, and comfort level during the different seasons. Along with the environmental parameters, clothing styles, culture, availability of adaptation measures, inevitable climatic conditions etc., work as important factors, to determine the user's preference of satisfaction. Earlier thermal comfort studies conducted in Bangladesh already showed variation in perception of indoor environment and comfort conditions of inhabitants, compared to the countries with colder climates, where many of the standards were originated. As no research has been found on this topic in context of Bangladesh, this investigation was initiated as an attempt to fill that gap. Therefore, this study tried to understand the effect of indoor thermal condition of in-patient wards on patient's perception, thermal sensation and thermal comfort level through field investigation of in-patient hospital wards in Dhaka during the critical time period of the year which will be identified in the next chapter.

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CHAPTER 3
FIELD INVESTIGATION

General Overview

Criteria for selection of study area and case-study

Sampling Strategy

Pre- survey works

Data Collection

Instruments for measurement

Different voting scales

Problems in field investigation

3.0 Introduction

The review of thermal studies in chapter two reveals that results and findings from field investigation are widely accepted for predicting comfort temperature of naturally ventilated buildings (Nicol and Humphreys 2002). As field studies are dependent on large number of respondents, its external validity is high. In this research, field investigation consists of a structured questionnaire survey, of occupant's thermal comfort perception in their actual living (habitable) environment, and simultaneous measurements of environmental parameters, along with recording of user's adaptation factors, such as thermal preferences and human behavioural adjustments and controls, which can be reasonably assumed to be helping them, to improve their thermal condition.

3.1 General Overview

This research focuses on investigation of the perception of thermal condition and comfort status, in non-air conditioned inpatient wards in Dhaka, during the warm humid seasons (June-September), which is considered to be one of the most critical time of year, in terms of thermal stress in tropical countries like Bangladesh (See Chapter-2, Section-B for Climate of Dhaka). The main objective of this study was to explore the current condition of the non-air conditioned inpatient wards, to investigate patient's perceptions and preferences regarding these conditions, along with their different behaviourial adaptations, that influence their thermal comfort perception in the given environment.

Multiple reviews of thermal comfort (chapter-2, section-A: Literature Review) has revealed that the results from field measurements are widely accepted, for predicting the comfort temperatures of naturally ventilated buildings (Nicol and Humphreys 2002). Also, as field studies are typically dependent on a large number of respondents, they can enhance the external validity of any research. But the studied hospital is not completely dependent on natural means nor is it completely mechanically controlled or air conditioned. Only a handful of studies were found in a similar context. Based on these studies, it can be assumed that the same process will work for these non-air conditioned spaces as well.

The methodology of this research consists of subjective study of questionnaire responses from patients during the field study, combined with an objective study of the micro climatic parameters, aiming to investigate the relationship between these thermal responses, and the simultaneously measured climatic variables. Both of the exercises were carried out in different non-air conditioned wards of the selected case study, a medical college hospital in Dhaka, to achieve the objectives in Chapter-1.

3.2 Criteria for selection of study area and case-study

3.2.1 Why Dhaka?

As Dhaka is situated at the central position of Bangladesh, it has a relatively moderate climate compared to other regions of the country which has climatic extremities. Another of the consideration was that pressures of development within urban Dhaka, call for relative small sites, which are often not regularly shaped. A Government hospitals trend to be repetitive proto types, this make fitting the design in a challenge for the architects, particularly for the non-air-conditioned ones. Also, compared to other divisions of Bangladesh, there is a wide availability of related data and resources regarding the capital city. Researcher's familiarity with Dhaka can add valuable insights to the investigation. Moreover, Dhaka providing case of access, as the researcher had to travel to the studied hospital (in Dhaka) for 17 days, with intervals for data collection, which would have been difficult to conduct from any other location.

3.2.2 Age group of respondents:

According to Zastrow/Kirst-Ashman (2007), youth adulthood can be considered the healthiest time of life. Young adults, aged between 20 to 40 years, are generally in good health, subject neither to disease nor the problems of senescence (Amreen 2010). Research showed that elderly people voted their thermal sensation 0.5 scale units (on a 7-point thermal sensation scale) lower compared to the young adults. (Schellen, et al. 2010) It also indicated that the elderly often tend to prefer a higher temperature in compared to their younger counterparts. (Schellen, et al. 2010) So, it can be assumed that if the young patients find the indoor environment comfortable, then it will be comfortable for the rest of the older patients as well.

3.3 Sampling Strategy

The process of selection of hospital, in-patient wards and patients are described below:

3.3.1 Selection of hospital:

Selection of hospital was based on the following criteria-

- Hospitals should be located in Dhaka
- Layout of the In-patient wards should follow the typical proto type design of current Government medical college hospitals.
- The accessibility of data and information collection can be ensured.
- Co-operation of patients and hospital staffs can be assured to conduct the questionnaire and photographic survey.

After considering all these factors, among the 15 medical college hospitals only 3 hospitals in Dhaka Division were found eligible according to the above criteria. But Kishoregonj medical college hospital and Tangail Medical Hospital were under construction during the field investigation and were not in similar micro climate of that of Mugda 500 Bed General Hospital, the only running hospital. Therefore, only Mugda 500 Bed General Hospital was chosen as a case study for this research.

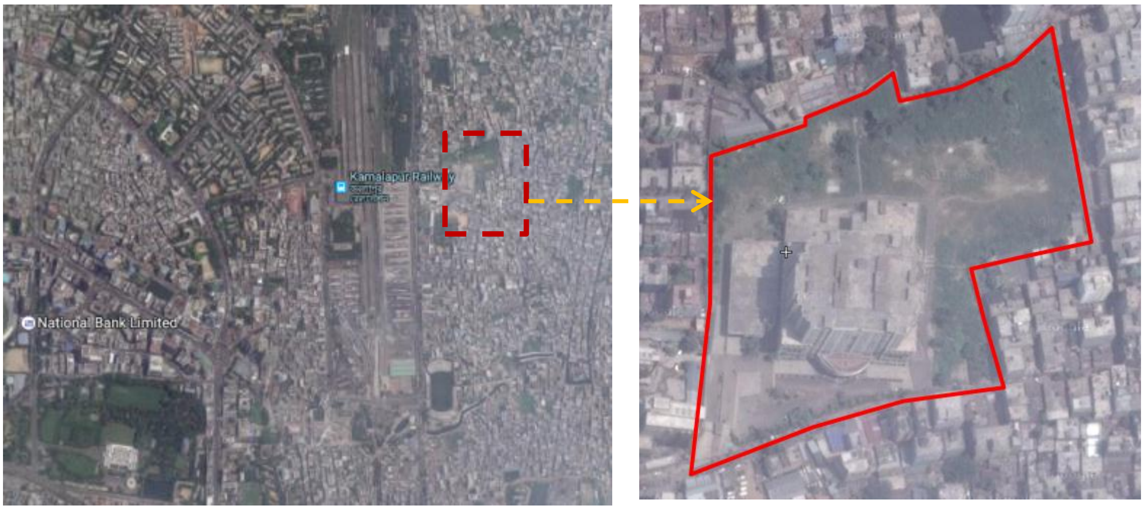


Figure 3.1: Locations of selected hospital (Mugda 500 Bed General Hospital)

Figure 3.2: View from North-West side and West side

3.3.2 Selection of wards:

For selection of wards, the following factors were considered-

- Wards had to contain patients within the selected age limit of the research (20-40years)
- Wards with similar layout were chosen.Wards had various scopes available to the patients for behavioural adjustments like increasing fan speed, opening windows, access to of airy spaces (Verandah or terrace) etc.

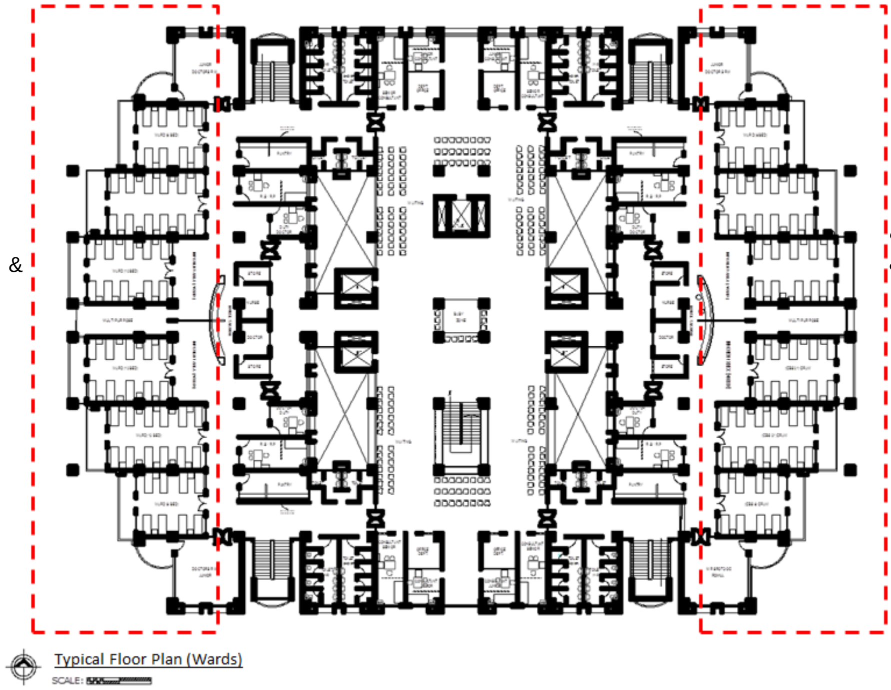


Figure 3.3: Typical floor plans containing In-patient wards

Considering the above criteria, patients of medicine and surgery wards were chosen for this research. Pediatric wards consisted of underage patients. Patients of ICU and CCU were in poor health and would be unavailable for repeated questioning. The ward layout of Obstetrics and Gynecology, were different from the typical ward layout. That's why these wards were excluded from this research.

All the floors had similar layouts for in-patient wards (Fig 3.4), and each of the wards consisted of 6 ward rooms. These 18 ward rooms can be categorized into three types, based on their different sizes. According to their capacity of holding patients, the rooms have been divided into 8 bedded, 10 bedded and 12 bedded ward rooms. One sample of each type of wards with proper plan and sections are given in Figures 3.5 - 3.7.

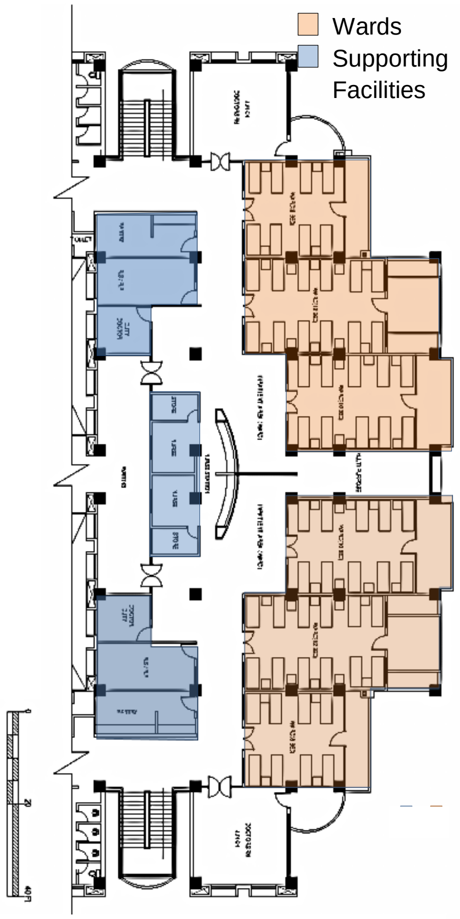
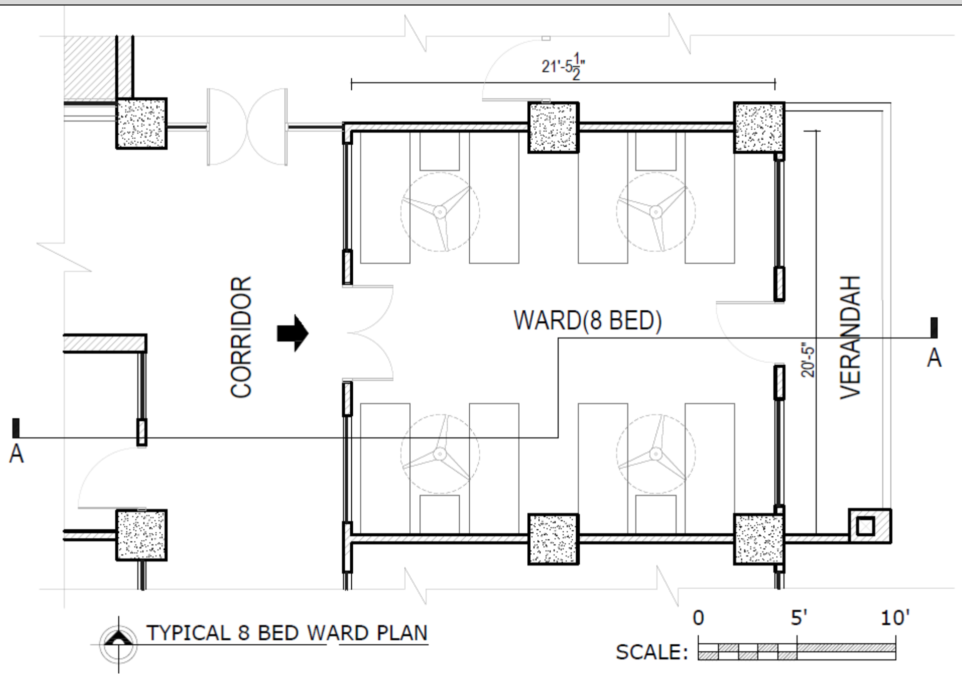


Figure 3.4: Plan of in-patient ward

<table>
<tr><th></th><th>Plan, section and interior view</th></tr>
<tr><td rowspan="3">Typical
8-Bedded
ward room</td><td>


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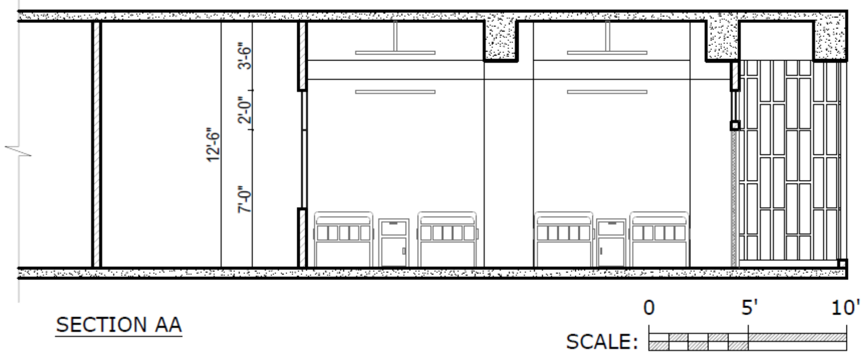

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Figure 3.5: Plan, section and interior view of ward rooms with 8 beds

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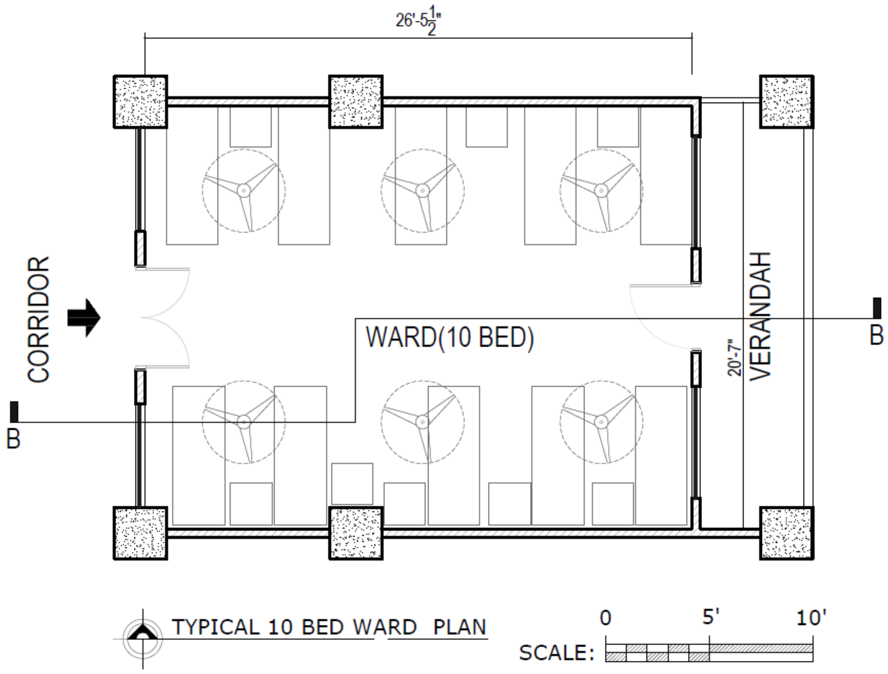
<tr><th></th><th>Plan, section and interior view</th></tr>
<tr><td>Typical 10-Bedded ward room</td><td>


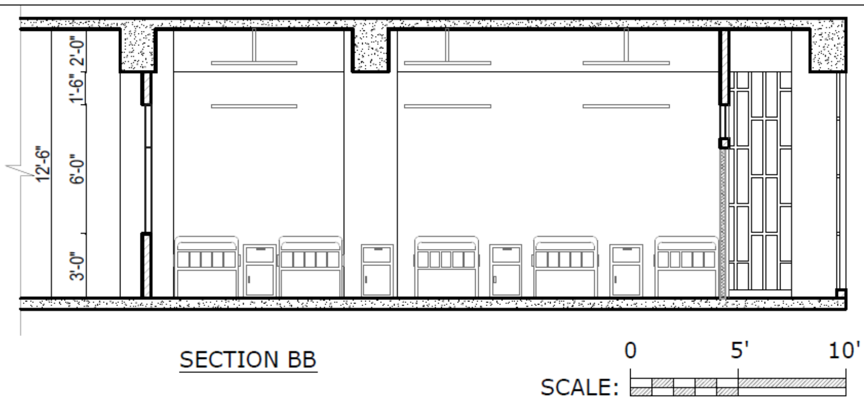



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Figure 3.6: Plan, section and interior view of ward rooms with 10 beds

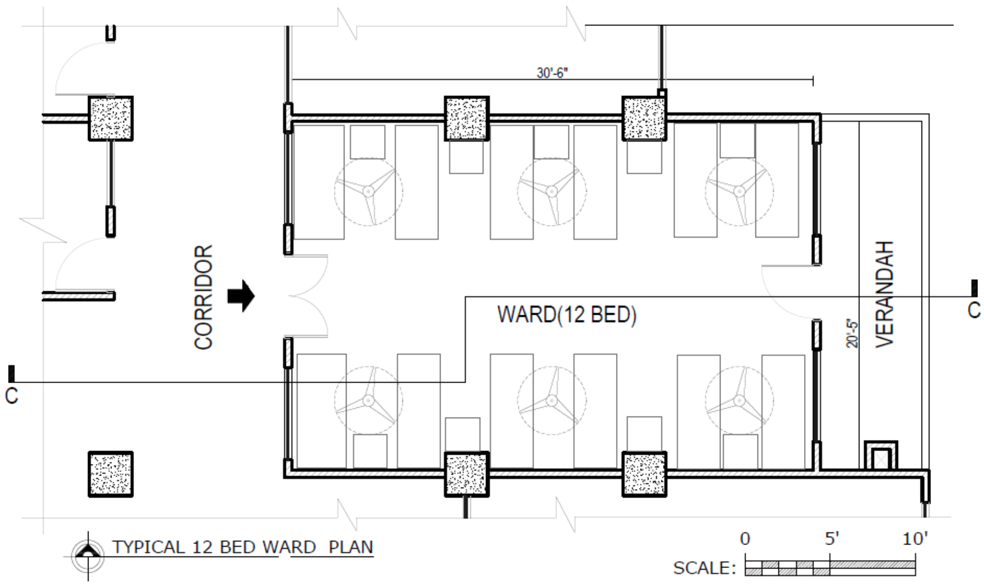
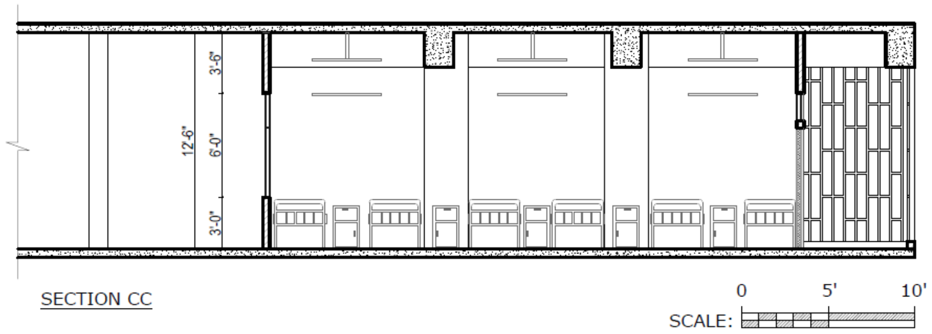
	Plan, section and interior view
Typical 12-Bedded ward room	
	
	

Figure 3.7: Plan, section and interior view of ward rooms with 12 beds

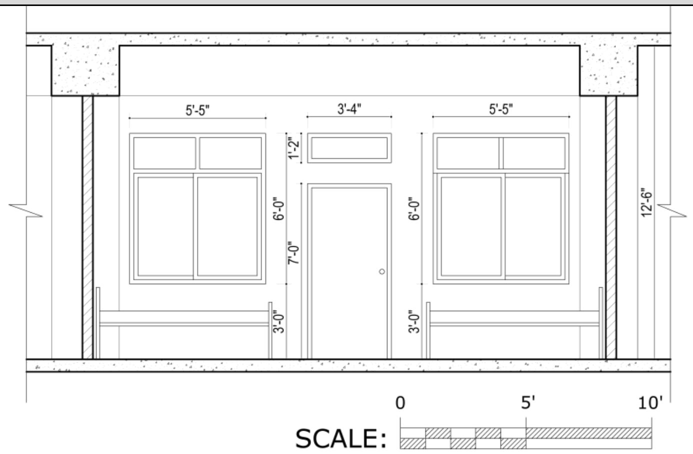
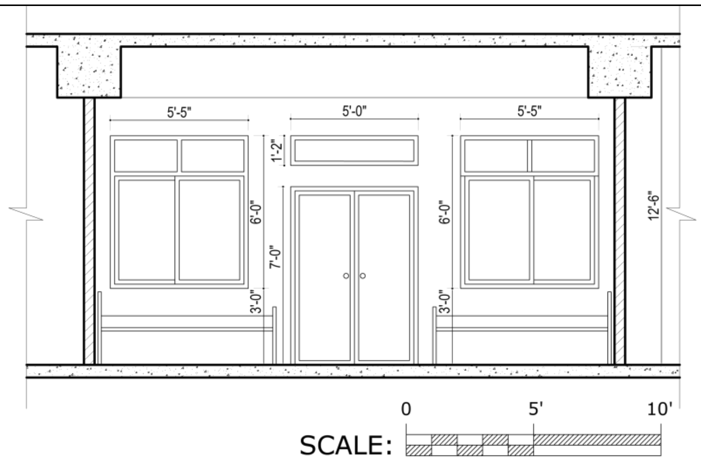
	Elevations
Typical elevations	
	

Figure 3.8: Typical Elevations of East and West wall

3.3.3 Selection of Patients:

Numerous factors can influence occupant's perception of thermal comfort and indoor thermal condition (see fig-2.4). All the significant factors are required to be neutralized to prepare a similar base condition for questionnaire investigation for the respondents.

Generally micro environmental factors can be considered similar for in-patient ward rooms, as they form parts of the same hospital, having identical layouts. All the ward rooms considered were East West oriented, with openings on one side (via verandah or terrace) and had similar options of adjustments.

To neutralize the other non-environmental factors, patients aging 20-40 years, with average height and weight, brown skin, and of same social class, were chosen for the research. Patient's health condition directly affects their perception of thermal comfort (Hwang et al, 2005). So patients, who stated their health as frail or moderate, were chosen. Patients with certain diseases, such as-high or low blood pressure, blood deficiency, TB, Thyroid problem, fever etc., were excluded as these diseases can affect their thermal perception As the normal length of stay for patients are 1-7 days (except few cases), patients who have stayed in the wards for more than 3 days were chosen to allow a certain level of familiarity with adaptation options, available within the wards. All the samples were in summer clothing (Clo value**:** 0.24-.5 clo) (Fig 2.3) and engaged with sedentary works (less than 1 met) (Table-2.1) immediately before the questionnaire-response session.

3.3.4 Selection of Sample size:

As the number of the patients, who fit to the established criteria of the research was different, on each day of the field investigation, it was difficult to determine a sample size from established formulas. So, a random sampling method was adopted to collect the data from 180 beds of Medicine and surgery wards. 200 patients who met all the set criteria stated previously were selected for this survey (minimum 12 patients per day). Data was collected from a structured questionnaire via one to one interview with each patient, for approximately 10-15 minutes.

3.4 Pre- survey works

Prior to the main survey, a pilot survey was conducted at the same hospital in the month of February. The patients were surveyed through a structured questionnaire while the environmental variables (Air temperature, Relative humidity and Air velocity) were measured simultaneously. During the 5 day survey period the temperature range was between 26.4-29.6^{0}C and relative humidity was between 49.22-72.64%. The air temperature was higher than ASHRAE standards, yet it was within the comfort range found in earlier studies in the context of Dhaka (see Chapter 2: Section A: Table 2.8). Majority of the patients felt the indoor environment was comfortable and acceptable, which clearly indicated that patients had clear perception regarding their indoor thermal condition.

The pilot survey revealed, that the necessity of knowing patient’s health condition, and type of illness beforehand, ensures non-biasness in the questionnaire survey. People, who are very ill, often fail to understand the questions, whereas some illness (Thyroid dysfunction, blood pressure, diabetes etc.) affects one’s thermal perception. Patients, under these criteria, were therefore excluded from the actual survey conducted later. Although patients with fever were excluded when the criteria were set, the pilot survey revealed otherwise. According to doctors, fever is not a disease, but rather a symptom, that indicates an underlying disease process (infection, autoimmune disease etc.). About 65% of the patients surveyed, during this survey were found to have fever due to different reasons. So, as the research is about the thermal comfort of the sick patients, these patients had to be included to obtain a more authentic data.

Also, it was found that length of stay is crucial, as patients who stayed for a short period (1-2 days), felt uncomfortable within the wards due to a new setting, less privacy and severity of illness. As a result, a feeling of negativity has been noticed during their interview and voting. But patients who had stayed more than 3 days started to get adapted and familiar to the new settings, which resulted in greater tolerance for the indoor environment and non-biased data was obtained during the actual questionnaire survey.

As most of the patients were illiterate and in poor health, the researcher had to conduct one to one interview with patients individually, and had to fill the questionnaire according to the patients responses. It was also found that if the motive of the research were explained properly to the patients, prior to their interviews, they were able to participate in the survey more sincerely, thus increasing the authenticity of their votes or responses.

3.5 Data Collection

Considering the pilot survey, responses and the observations noted during, minor corrections were done to the questionnaire. As human perception is not a simple “stimulus-response” (cause-effect) phenomenon, two types of data (both objective and subjective measurements) are believed to be essential to comprehend complex human perception, behaviour and background; as a part of the data collection process (Feriadi et. al, 2003). Prior to the interview, the patient was briefed about the survey, and each of them was interviewed in a transverse way.

The survey was conducted on 17 separate days, with an interval of 14-16 days between each set of survey, over the four months of the warm humid season (June to September, 2017). A total of 200 patients from medicine and surgery in-patient wards, were interviewed twice a day. Because of the interval times and indefinite time of patient’s length of stay, the same patients were not always available for the next survey. That is why a patient was questioned twice; in the morning (8.30-10.30hrs) and in the afternoon (02.00-04.00hrs) of the same day. Around 10-13 patients were interviewed each day and a total of 400 data (200 X 2) was collected from these interviews. The date and ward names are given in Table 3.1 below.

Table 3.1: Date of field survey and surveyed in-patient wards

Day	Date	Ward name
1	**06.06.17**	Surgery Dept. (General Surgery & Urology)
2	**07.06.17**	Surgery Dept. (Orthopedics, Eye, ENT) Medicine Dept. (General)
3	**10.06.17**	Medicine Dept. (General)
4	**08.07.17**	Surgery Dept. (General Surgery & Urology)
5	**09.07.17**	Medicine Dept. (General) Surgery Dept. (Orthopedics, Eye, ENT)
6	**10.07.17**	Surgery Dept. (Orthopedics, Eye, ENT)
7	**28.07.17**	Medicine Dept. (General)
8	**30.07.17**	Surgery Dept. (Orthopedics, Eye, ENT)
9	**01.08.17**	Surgery Dept. (General Surgery & Urology)
10	**15.08.17**	Medicine Dept. (General)
11	**16.08.17**	Surgery Dept. (General Surgery & Urology)
12	**17.08.17**	Surgery Dept. (Orthopedics, Eye, ENT)
13	**18.07.17**	Medicine Dept. (General)
14	**25.08.17**	Medicine Dept. (General)
15	**26.08.17**	Surgery Dept. (General Surgery & Urology) Surgery Dept. (Orthopedics, Eye, ENT)
16	**14.09.17**	Surgery Dept. (General Surgery & Urology) Surgery Dept. (Orthopedics, Eye, ENT)
17	**15.09.17**	Medicine Dept. (General)

Environmental variables (Air temperature, relative humidity and air velocity) were measured with proper instruments (Section 3.6) simultaneously with the interview. Also, secondary data for outdoor environmental variables were measured manually by the researcher.

Data regarding patient's background (age, gender, social class, culture etc.), perception (sensation, preference etc.) and behaviour (Control over space, adaptation etc.) were collected through a questionnaire survey. Whereas personal factors like metabolic rate and clothing were recorded from observation by researchers and environmental parameters were measured using proper instruments.

Data from both the questionnaire survey, and measurements of environmental parameters, can be used for proper statistical analysis (by using statistical software, IBM SPSS-Statistics 23, 2015 and Microsoft Excel), in order to produce meaningful and reliable indicators of relationships between the responses and environmental condition. The main process followed in relating the data is given in Fig 3.9.

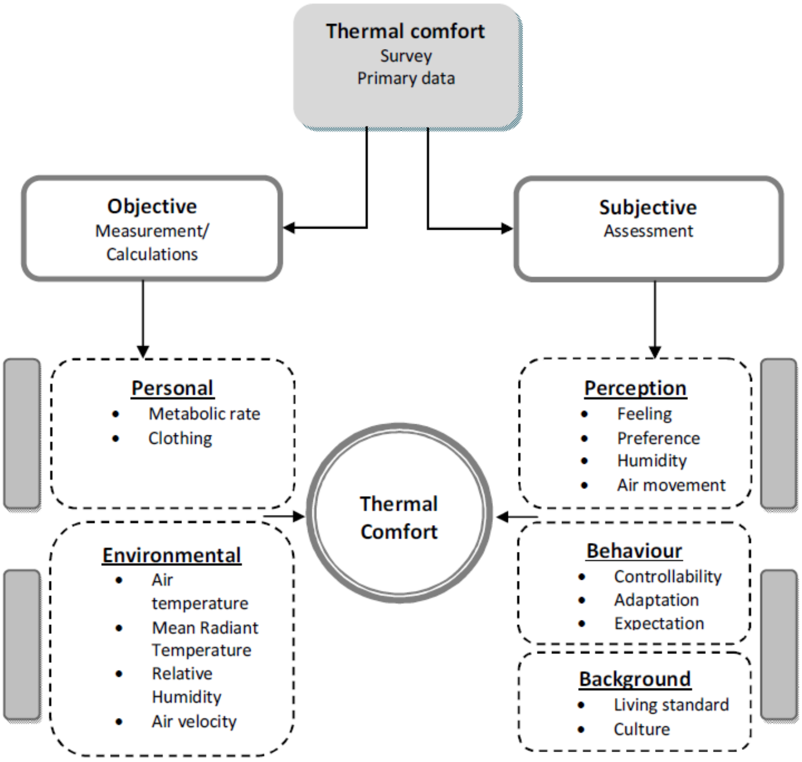


Figure 3.9: Objectives and Subjective Measurement in Thermal Comfort Survey (after Feriadi 2003).

3.5.1 Questionnaire Interview

A questionnaire was prepared for data collection which was based on ASHRAE 55-2004 Informative Appendix E 'Thermal Environment Survey', McCartney. *et al* (2002) and questionnaire used by other researchers working in similar climatic conditions. (Wong and Khoo, 2003) (Wong et al., 2002) (Shajahan , 2012) (Tariq , 2014)

The subjective responses, on various comfort votes regarding different environmental parameters, such as temperature, humidity, and air velocity, along with a response on overall thermal comfort was obtained through the questionnaire. Basic data of the respondents such as, age, gender, height, weight, clothing, immediate last activity before the survey, etc. were also gathered through the questionnaire, and by observation of the researcher. Most of the subjects were found to be either illiterate, or in poor health, having little ability to individually filling the questionnaire. Thus, all respondents gave answer to each and every question orally, and the researcher kept the written record, by filling up the questionnaire format, according to the respective responses [Appendix 05]. Patients were also questioned regarding other aspects, such as preference to use environmental control, behavioural adaptation etc. Bed position in the ward, number of doors and windows etc. were recorded according to the observation of the researcher. Responses gathered from this questionnaire, were analyzed and co-related with each other, and also with measured environmental data. A sample questionnaire that was used for survey is given below.

Assessment of Thermal Condition of Naturally Ventilated Adult In-patient Wards During Warm Periods in Dhaka : Mugda 500 Bed General Hospital

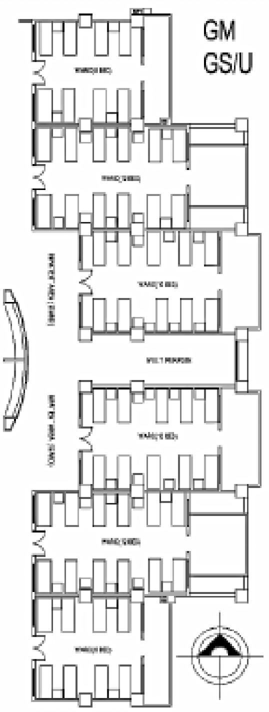
Date: ____________

I) General Information:

1. Sample No : ________________________________
2. Age: O 21-25 O 26-30 O 31-35 O 36-40
3. Gender: O Male O Female
4. Height: ________________ 5. Weight: ____________________
6. Skin Colour: ______________
7. Prior Experience of Hospital Stay: O Never O 1-2 O 3+ O ________________
8. Length of Stay (Days): O 1-2 O 3-4 O 5-6 O 7+ O ________________

II) Location/Position:

1. Which Floor of the building?: O 6th Floor O 8th Floor
2. Name of department O Surgical (Ortho/Eye/ENT) O Surgical (GS/Urology) O Medicine (Gen) O Medicine (Nephrology)
3. Location in the room/bay: O Near the window O Near the aisle O In between O Other
4. Are you near an exterior wall (within 15ft)? : O Yes O No
5. Are you near a window (within 15ft)? : O Yes O No



III) Control of space:

1. Which of the following do you personally adjust or control in your space?
   - O Window shades O Operable Windows
   - O Door to interior space O Door to exterior spaces
   - O Ceiling fan O Portable fans
   - O Natural lights O Artificial light
   - O None of this O Other________________

IV) Physical Condition:

1. How do you describe your physical strength?
   O Vigorous O Moderate O Frail O Very frail
2. Do you have any of the following Disease?
   OTB OBP O Fever
   O Hyper/Hypo Thyroidism O Heat Stroke

V)

1. Do you experience change in indoor temperature during the day cycle?
   O Extreme Change O Huge Change O Slightly change
   O Very little change O No Change
2. When do you experience the highest thermal discomfort?
   O Morning (<11) O Mid-day (11-2) O Afternoon (2-5)
   O Evening (5<) O Always O Other

Time: ____________________ **T:** ______ **RH:** ______ **AV:** ____

VI) Metabolic rate:

1. What is your current activity?

Reclining	Seating	Standing	Walking	Others

2. What did you eat/drink in the last 30 minutes? ________________________________

3. What was your last activity within the last 30 minutes?

Reclining	Seating	Standing	Walking	Others

VII) Clothing Insulation:

1. What you are wearing now?
   O Saree O Salwa Kameez O Long dress (Maxi)
   O Blouse O Under garments O Covered head (Orna)
   O T-shirt O Lungi O Trousers
   O Undershirt O Panjabi O Pajama
2. Are you covered with something? O Yes O No
3. If yes, what are you covered with? O Bed sheet O Katha O Other ________________

VIII) Temperature:

1. Thermal Sensation
How are you feeling at this current environment?

-3	-2	-1	0	1	2	3
Very cold	Cool	Slightly Cool	Perfect	Slightly Hot	Hot	Very Hot

2. Thermal Comfort:
How are you feeling at this current environment?

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3. Thermal Preference:
How do you like air temperature to be in your space?

-3	-2	-1	0	1	2	3
Extreme cold	Much Cooler	Slightly Cooler	No change	Slightly warmer	Much warmer	Extreme Hot

4. If there any source of heat in your space/ward? If yes, specify.______________________________

IX) Humidity:

1. How are you feeling (regarding humidity) inside the ward? (Sensation)

-3	-2	-1	0	1	2	3
Extremely Dry	Too Dry	Slightly Dry	Perfect	Slightly Humid	Very Humid	Absolute Humid

2. How are you feeling (regarding humidity) inside the ward? (Comfort)

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3. How do you like humidity to be in your space?

-3	-2	-1	0	1	2	3
Extremely Dry	Much Drier	Slightly Drier	No change	Slightly Humid	Much Humid	Extreme Humid

4. How is your skin, in term of wetness?

Very Dry	Dry	Just right	Drops of sweat	Wet

X) Air quality:

1. How are you feeling (regarding air circulation) inside the ward? (Sensation)

-3	-2	-1	0	1	2	3
Absolute Still	Too Still	Slightly Still	Just right	Slightly Breeze	Very Breeze	Highly Breeze

2. How are you feeling (regarding air circulation) inside the ward? (Comfort)

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3. How do you like air quality to be in your space?

-1	0	1
Less Ventilation	No Change	More Ventilation

XI) Thermal Acceptability:

1. Is the thermal environment of your space acceptable at this moment?

-3	-2	-1	0	1	2	3
Not acceptable				Acceptable		

XII) Adaptation Measures:

1. When feeling 'hot' which type of measurement do you undertake?

Increase speed of ceiling fan	Changing levels of clothing/ covering	Change posture	Washing part of body/ Take Shower	Use Hand fan/ Table fan	Going outside room/ airy space/ Verandah	Others ______________

2. Do you think the thermal comfort inside the wards have impact on your smooth recovery?

-1	0	1
Interferes	No Effect	Enhances

3. How do you think, your recovery will be faster by what type of change in your ward?

Increase number of ceiling fan	Increasing area of Window	Increasing air ventilation inside ward	Changing position/ orientation of ward	Reducing Humidity level	Reducing temperature level	Others ____________

3.5.2 Criteria for data collection:

To minimize any error and to maintain uniformity throughout the study, the researcher set the following criteria for data collection.

- Patients should be physically and psychologically stable during interview.
- Sample patient was engaged in sedentary activity only (reclining, seated, relaxed) for at least half an hour before the survey, so that their metabolic rate was 1 met (maximum).
- Patients were allowed to wear the normal clothing according to their gender, cultural, social and traditional setup.
- Measurement were taken of all physical environmental variables (air temperature, relative humidity and air velocity) thrice at 1m height or at the level of patients bed and instruments were placed close to the sample to record the environmental conditions simultaneously. The average of the three measured environmental variables was used for analysis.
- Questions regarding thermal comfort perception and sensations were repeated twice or thrice, after a regular interval, to match the responses, and to ensure authenticity of the obtained data, regarding actual comfort feeling of respective respondents at the particular time of questioning.

3.6 Instruments for measurement:

Mainly two instruments were used to measure all the environmental data, i.e. Air Temperature, Relative Humidity and Air Velocity of the indoor spaces, during each patient's interview, as well as for outdoors (Fig-3.10 and 3.11). Instruments used for the survey were selected after fulfilling the criteria of accuracy, easy portability and usability during the site visits, for instant collection of data, which was the prime concern. Instruments that were used for this research are stated below:

3.6.1 For air temperature and relative humidity

To measure air temperature and relative humidity of both indoor and outdoor, a Digital Thermometer Hygrometer (Zeal PH1000) was used. It is a high quality digital or hygrometer which has been used for thermal comfort studies previously.

Table 3.2: The specification of Digital Thermometer Hygrometer (Zeal PH1000)

Item	Specification
Measuring Range	-50ºC/+70°C and °F
	+10%RH to 99%RH
Accuracy	=+/- 1 degree C
	Humidity +/- 5% RH
Temperature and Humidity	Min / Max record

Fig 3.10 & 3.11: Image of Digital Thermometer Hygrometer (Zeal PH1000) and Image of Mini Thermo Anemometer (Extech 45118)

3.6.2 For air velocity:

A Mini Thermo-Anemometer (Extech 45118) was used for measuring Air flow. Air temperature was also collected simultaneously, that helped to cross check the previously collected data. This instrument was a waterproof pocket sized device to record air velocity and air temperature.

Table 3.3: The specification of Mini Thermo Anemometer (Extech 45118)

Measurements	**Range**	**Resolution**	**Basic Accuracy**
m/s (meters per second)	0.5 to 28m/s	0.1m/s	± (3%rdg + 0.2m/s)
ft/min (feet per minute)	100 to 5500 ft/min	20ft/min	± (3%rdg + 40ft/min)
km/h (kilometers per hour)	1.8 to 100.6 km/h	0.7km/h	± (3%rdg + 1.4km/h)
MPH (Miles per hour)	1.1 to 62.5 MPH	0.2MPH	± (3%rdg + 0.4MPH)
knots (nautical miles per hour)	1.0 to 54.3 knots	0.3knots	± (3%rdg + 0.6knots)
Beaufort Force	1 to 17 BF	1 BF	± 1
Temperature	-18 to 50°C (0 to 122°F)	0.1°C /°F	±1°C /±1.8°F
Power	CR2032 Lithium battery		
Dimensions	5.25 x 2.75 x 0.75" (133 x 70 x 19mm)		
Vane	1"(24mm) diameter		
Weight	3oz (95g)		

3.7 Different voting scales

The following scales were all included in the questionnaire. These responses were later related to the measured environmental data to establish any relationships to each other.

3.7.1 Sensation scales

Patient's responses regarding sensation of thermal environment (air temperature, relative humidity and air velocity were recorded by using the following scales (Table-3.4).

Table 3.4: Sensation scales for Air Temperature, Relative Humidity and Air Velocity

	-3	-2	-1	0	+1	+2	+3
Thermal sensation	Very cold	Cool	Slightly Cool	Perfect	Slightly Hot	Hot	Very Hot
Sensation regarding indoor relative humidity	Extremely Dry	Too Dry	Slightly Dry	Perfect	Slightly Humid	Very Humid	Absolute Humid
Sensation regarding indoor air velocity	Absolute Still	Too Still	Slightly Still	Just Right	Slightly Breezy	Very Breezy	Highly Breezy

3.7.2 Comfort scales

Comfort responses of patients regarding Air Temperature, Relative Humidity and Air Velocity were recorded by using a 7 point ASHRAE scale.

Table 3.5: Comfort voting of air temperature, relative humidity and air velocity

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3.7.3 Preference scales

To cross match the comfort votes with preference regarding the three environmental parameters the following scales (Table-3.6) were used for this research, following McIntyre's scale (McIntyre ,1980).

Table 3.6: Preference Scale of air temperature, relative humidity and air velocity

Air Temperature	-3	-2	-1	0	+1	+2	+3
	Extreme cold	Much Cooler	Slightly Cooler	No change	Slightly warmer	Much warmer	Extreme Hot
Relative humidity	-3	-2	-1	0	+1	+2	+3
	Extremely Dry	Much Drier	Slightly Drier	No change	Slightly Humid	Much Humid	Extreme Humid
Air velocity	-1			0	+1		
	Less Ventilation			No Change	More Ventilation		

3.7.4 Other scales

In the questionnaire, the patients had to vote on the level of acceptability in the current environmental condition, as well as its impact on their recovery, based on the following scales (Table-3.7 & 3.8).

Table 3.7: Subjective scales of 'acceptability' used in this thermal study

-3	-2	-1	1	2	3
Not acceptable			Acceptable		

Table 3.8: Subjective scales of 'perceived impact on recovery used in this thermal study

-1	0	1
Interferes	No Effect	Enhances

3.8 Problems in field investigation

In this research, environmental measurements acted as independent variable whereas comfort votes worked as dependent variables. From multiple investigations, it can be seen that the most accepted methods of analysis for field surveys, is to use statistics. As most of the patients were free to have their own clothing, posture, activity level etc., all these could have direct impact on their voting. To neutralize these varied factors, as much as possible, samples were chosen whose clothing and activity level were within the set limit of the research. So, any formula generated from this statistical process, must be treated with extreme caution, and any such formula should be judged on physical, as well as statistical grounds (Shajahan, 2012).

3.9 Summary

This chapter has described the overall process for field investigation which included selection of hospitals, ward rooms, and criteria to select the 200 sample patients. Data collection process was administrated through standard questionnaire format, containing established rating systems for subjective response, and measurement of environmental data simultaneously. Further analysis was conducted by matching these subjective and objective data, and by using statistical software (SPSS), to study the thermal comfort of patients, in the current setting, to find out their comfort range, and finally to identify a 'neutral' temperature and relative humidity that will satisfy their preference, which will be discussed in the next chapter.

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CHAPTER 4

RESULTS AND ANALYSIS

Qualitative methods: Descriptive measurements

Quantitative Methods

Proposed Comfort Parameters and Comfort Zone

4.0 Introduction

This chapter will report on the subjective responses of patients [Appendix 07, Appendix 08] on various thermal comfort parameters [Appendix 06], and overall thermal comfort perception, which was obtained from the questionnaire survey, following the methodology described in Chapter-3, during warm humid seasons. The analysis and interpretation of the results that were obtained through matching these subjective responses, with the measured levels of different environmental parameters obtained during the questionnaire survey, have been discussed here as well.

A systematic framework has been applied to the collected data from field investigation to reveal qualitative and quantitative assessments and relationships. The quantitative methods put emphasis, on using proper statistical tools for evaluation, so that meaningful results and findings can be obtained. Through the evaluation and interpretation of the relationship between the various responses and concurrent measured environmental data, a better understanding of the patients perceptions of indoor thermal comfort, and comfort range in non-air conditioned inpatient wards in Dhaka, during warm humid periods can be revealed.

4.1 Qualitative methods: Descriptive measurements:

200 patients of surgery and medicine in-patient wards, of the case study hospital were interviewed twice a day for four months of warm humid season (June-September) of 2017. A total of 400 sets of data, were collected, along with their simultaneous environmental data. This section will discuss the subjective findings of the questionnaire investigation.

4.1.1 Age distribution:

As mentioned in the previous chapter, this research focused on young adults (aged 20-40 years) only. Fig 4.1 illustrates the age distribution of the entire data sample. The largest percentage of responses (33%, 120 responses) was represented by the age group of 20-25 years where as the smallest percent of respondents (18%, 72 responses) was from the age group of 31-35 years. The rest of the groups of 26-30 years and 36-40 years accounted for percentage of 27.50% (110 responses) and 21.50% (86 responses) respectively.

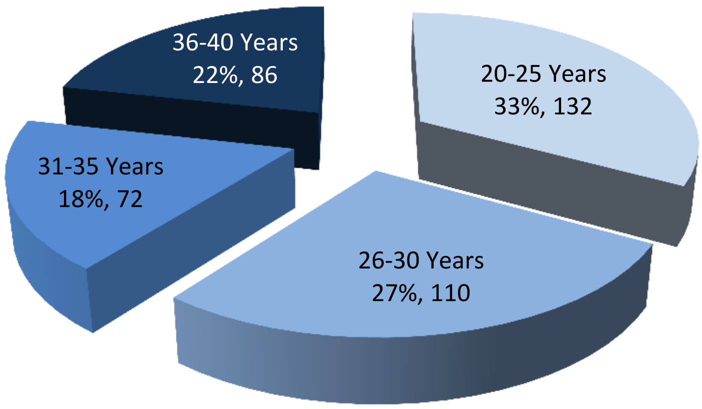


Figure 4.1: Age distribution of entire data sample

4.1.2 Gender distribution:

Fig 4.2 shows the gender distribution of the entire data sample where 53% (212 responses) and 47% (188 responses) responses were collected from male and female respondents respectively. No of respondents of both genders were almost equal.

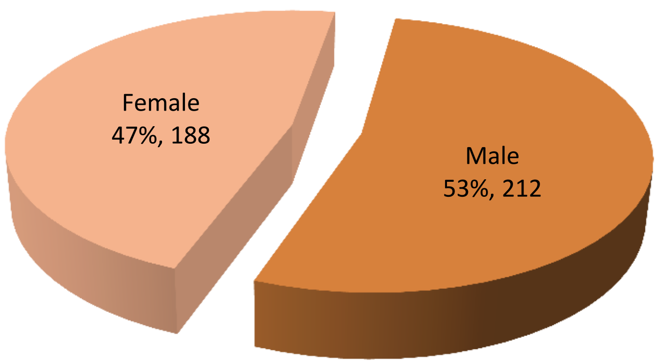


Figure 4.2: Gender distribution of entire data sample

4.1.3 Distribution according to Departments:

Among the wards under different departments for reasons mentioned in Section 3.3.2, only wards of the general medicine and surgery departments were surveyed. Among the 400 responses, 238 (59.5%) were from surgery department while the rest of 162 (40.5%) were from general medicine department. As the surgery department was divided into two wards, according to different specialties, the number of respondents from Surgery department was higher than the medicine department. Fig 4.3 exhibits a detailed distribution of respondents between these wards.

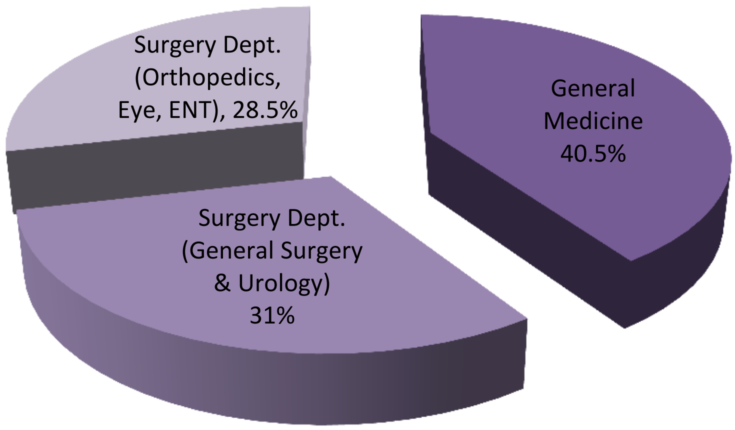


Figure 4.3: Distribution of entire data sample according to Departments

4.1.4 Personal parameters

To limit the variability regarding metabolic rate and clo value, a baseline was maintained to keep uniformity during the questionnaire survey. All the respondents were selected in a way that they were engaged in activity level between reclining (0.8 met) to seated at rest (1 met), prior to the interview.

It was also observed that the male respondents preferred to wear minimum clothing with bare upper bodies, where their clo value was only 0.24 (Shahjahan A., 2012) and for other summer clothing's clo value was maximum 0.3 clo. On the other hand, clothing insulation of female respondents was higher, as they were fully covered, due to religious and cultural compulsion, and their average clo value was 0.4 (Maxi) - 0.5 (Salwar Kameez, saree)

4.1.5 Thermal acceptability of In-patient wards

Fig 4.4 shows the thermal acceptability of the patients in inpatients wards in Dhaka during the monsoon period of the year. Only about 45.25% of the responses (181 responses) 'accepted' their immediate environments, whereas 54.75% of the responses (219 responses) found it 'unacceptable'. In details, only 2% of the patients out rightly voted their environment as 'unacceptable' [-2].

Range of Indoor Air temperature	28.95-33.45^{0}C
Range of Indoor relative humidity	65-86%
Range of Indoor air velocity	0.05-1.85 m/s

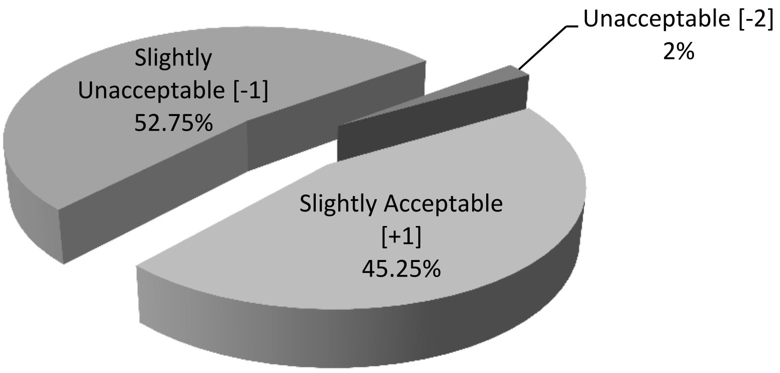


Figure 4.4: Distribution of 'acceptability' vote

To explore the reason of low thermal acceptability, voting on various environmental variables are investigated, which is discussed in the later sections.

4.1.6 Adaptive measure of respondents:

Respondents were also interviewed, about the adaptive measures, or actions, which they normally undertake, when they feel uncomfortable in the indoor environment of the in-patient wards. Fig 4.5 illustrates the adaptive measures of the respondents.

41% of the patients admitted that during critical times of thermal discomfort, they usually go to airy spaces, outside the wards, verandah etc., for a change of environment, which indicates their desire for thermal comfort. But many of the patients are often bound to their bed, and too weak to move around. So, they prefer adaptive measures, that they can use or manipulate easily. About 18% of the patients prefer to change their level of covering or clothing, according to their comfort requirements. Again, 13% of patients use hand fan, while 12% prefer to change their posture only.

Others, either increase the speed of the fan (8%), wash parts of their body, or shower (6%) to get rid of the thermal discomfort. Only 1% of the respondents prefer to reduce their activity level as an adaptive measure. It must be noted here that, most of the openings (window, doors etc.) of these inpatient wards, were always kept open to maintain proper ventilation inside. That is why this important adaptive measure was not mentioned by the respondents.

These responses indicate that patients were highly aware of their thermal discomfort, and that they took active measures, to change these uncomfortable thermal conditions.

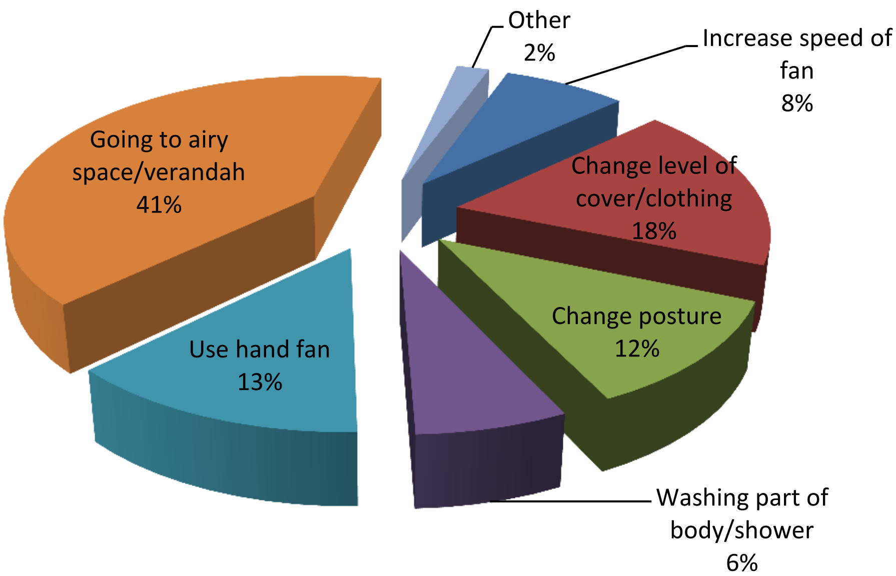


Figure 4.5: Distribution of adaptive measure of respondents

4.1.6 Perceived impact on recovery:

The respondents' perceptions, of the impact of environmental variables, on their recovery, will be discussed in this section. The occupants were asked to assess their own 'perceived' impact, on a subjective rating scale, as an approach for the assessment of their recovery, and its link to thermal comfort. Figure 4.6 shows that only 26.50% of the sample thought that the indoor thermal conditions were interfering with their recovery, while 73.50% thought that they have little to no effect on their recovery.

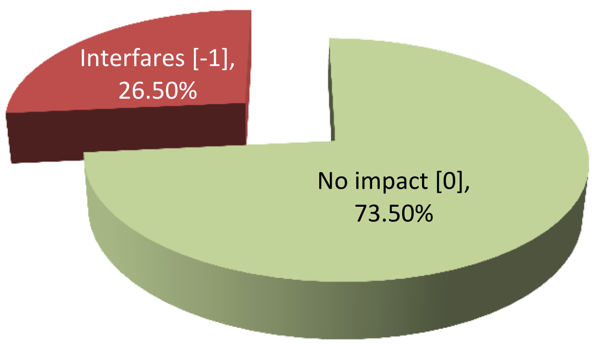


Figure 4.6: Perceived Impact on patient's recovery

4.2 Quantitative Results

4.2.1 Analysis of environmental parameters

Measurements were taken of both outdoor and indoor environmental parameters twice a day, for 17 days during the survey period (June to September), to coincide the measured parameters with the questionnaire survey [Appendix 06]. The outdoor environmental parameters were measured at 1m height above the level outside the selected wards, and the indoor environmental parameters were measured at 1m height above the floor, or, at the level of patient's bed, close to the patient and excluded from any direct solar radiation.

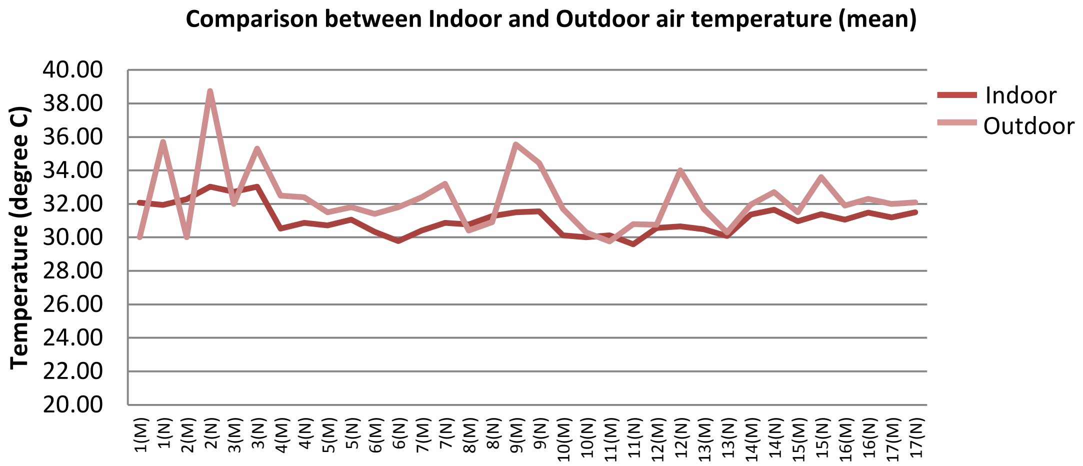


Figure 4.7: Comparison between indoor and outdoor air temperature (Mean)

Fig 4.7 and fig 4.8 reveal strong relationship between air temperature and relative humidity of indoor and outdoor. The variables increased and decreased in a similar pattern excluding a few exceptions for both cases.

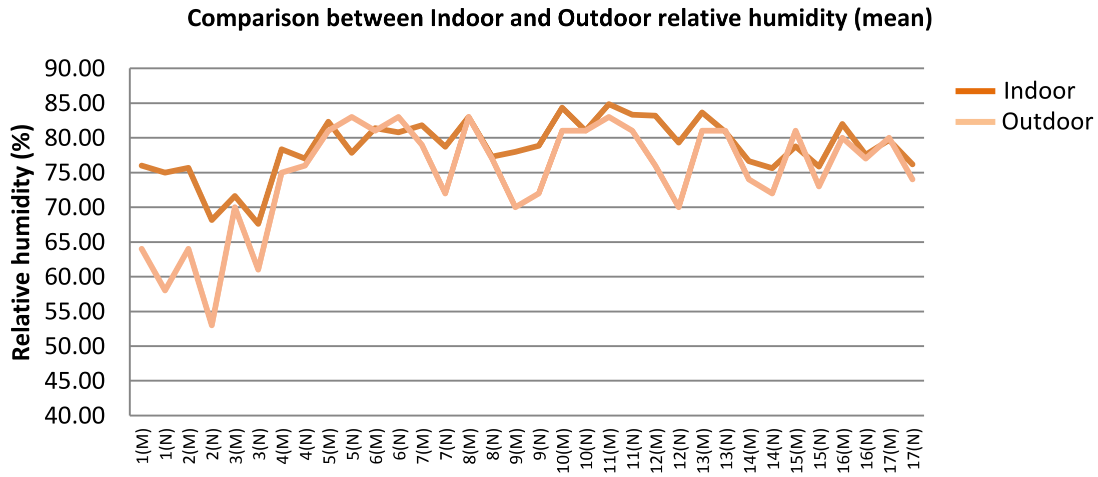


Figure 4.8: Comparison between indoor and outdoor relative humidity (Mean)

The indoor mean air velocity was normally found to be higher, compared to the outdoor values. This may be attributed to due to the position, number and orientation of openings, constant use of ceiling fans to avoid discomfort within the in-patient wards. Although openings of the hospital building were designed to allow fresh air from outdoors, but only a small amount of air comes inside the wards due to climatic conditions during survey days. So, patients were highly dependent on ceiling fans to ensure thermal comfort.

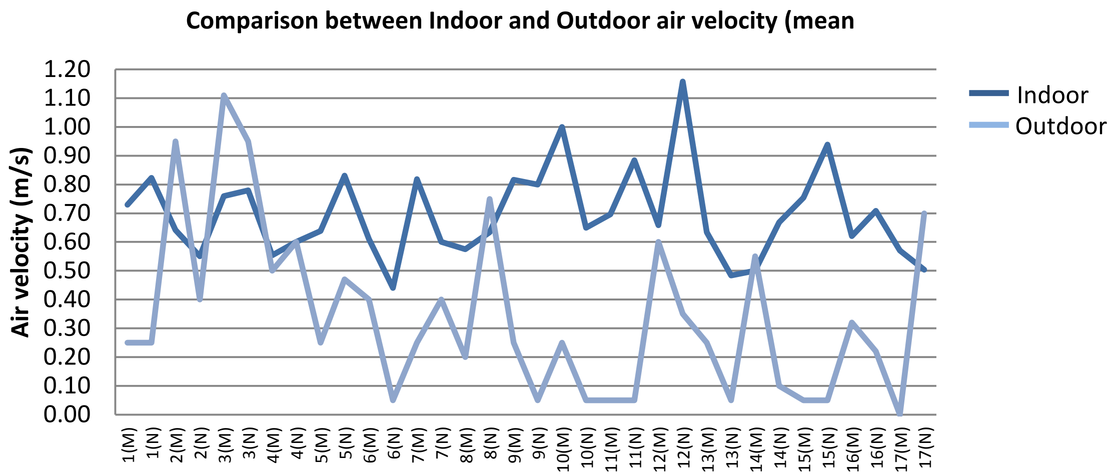


Figure 4.9: Comparison between indoor and outdoor air velocity (Mean)

4.2.2 Interpreting votes by respondents:

Patient's responses regarding three aspects: votes on 'Sensation', 'Comfort' and 'Preference' were discussed at first. Further analysis was done by relating these aspects to the three major environmental variables (air temperature, relative humidity and air velocity), that were measured simultaneously to the questionnaire survey

4.2.2.1 Votes on air temperature:

The votes on air temperature for the following three aspects: votes on 'thermal sensation', 'thermal comfort' and 'thermal preference' are discussed below.

4.2.2.1.1 Vote distribution of air temperature on thermal sensation scale:

In this research, the patients were asked to vote on their thermal sensation, based on ASHRAE's 7 point scale of thermal sensation (ASHRAE Standard 55-1992) (ASHRAE Standard 55-2004). Fig 4.10 shows that among 400 responses 8.5% (34) votes indicated their thermal sensation as 'hot' [+2] and 47.5% (190) as 'slightly hot' [+1], whereas 42% (168) votes shoe the indoor thermal condition as 'perfect' [0]. Only 2% (8 votes) of the responses were for 'slightly cool' [-1].

Range of Indoor Air temperature	28.95-33.45^{0}C

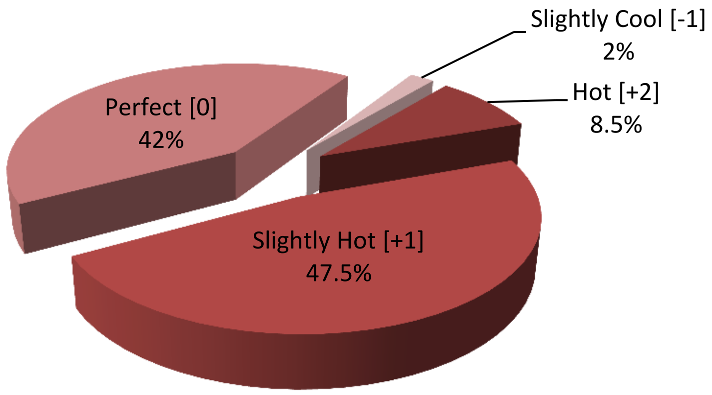


Figure 4.10: Vote distributions on thermal sensation

According to ASHRAE's 7 point scale of thermal sensation, when 80% of the occupants vote for the central three categories (vote= -1, 0, 1), the indoor thermal condition can be considered as acceptable (ASHRAE Standard 55-1992) (ASHRAE Standard 55-2004). In this research about 91.5% responses lie within these categories, which shows that although all the patients were not in absolute thermally acceptable conditions, but the indoor conditions were close to acceptability. Only 8.5% responses were outside the three central categories of sensations.

The mean value of thermal sensation vote (TSV) was found to be 0.625 which lies between 'perfect' [0] and 'slightly warm' [+1]. But as the three central categories implied acceptability, it can be said that patient were satisfied with air temperature of their respective wards in general.

4.2.2.1.2 Vote distribution of air temperature on thermal comfort scale:

Comfort votes, regarding indoor air temperature, helped to cross check patients responses of the thermal sensation scale. From fig 4.11 it can be seen that 49.5% (198) of the responses vote for the indoor thermal comfort as 'slightly uncomfortable' [-1] and 5.5% (22) as 'uncomfortable' [-2], whereas 45% (180) indicate 'slightly comfortable' [+1]. Although 53.5% (220 responses) of the patients responses indicate that the indoor thermal environment condition is 'uncomfortable', 94.5% (378) responses were within the acceptable range (Between -1, 0, +1). Again from section 4.2.2.1.1, it was found that 91.5% votes showed their thermal sensation in between the central sensation range (-1, 0, 1). Comparison between thermal sensation votes and thermal comfort votes indicated close similarity between the two variables. It also proved that the patients seem to be well aware of their environment, and their responses regarding them were found to be consistent.

Range of Indoor Air temperature	28.95-33.45^{0}C

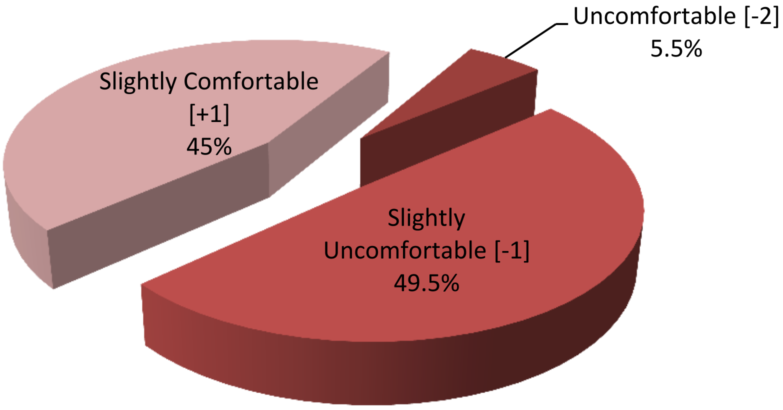


Figure 4.11: Vote distributions on thermal comfort

4.2.2.1.3 Thermal preference

The thermal preference responses, however, differ from the thermal sensation and thermal comfort vote distribution. In the preference scale (fig 4.12), 67.25% (269 responses) of the respondents preferred the indoor environment to be 'slightly cooler' [-1] and 7% (28 responses) of them voted for 'much cooler' [-2] while only 24.25% (97 respondents) of the respondents voted for 'no change' [0], and rest of them (1.5%) voted for 'slightly warmer' [+1].

Range of Indoor Air temperature	28.95-33.45^{0}C

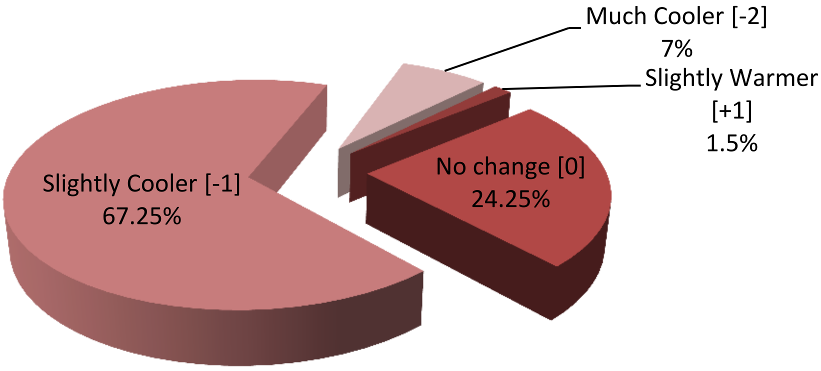


Figure 4.12: 'Preference' vote distribution of air temperature

Although from previous sections, it was found that 91.5% and 94.5% of the responses indicated their thermal sensation and thermal comfort within acceptable ranges, in the preference scale, a total of 75.75% of the responses indicated that they would like to change their environment to be cooler. This finding agrees with the studies by other researchers, where many responses within a neutral zone, claiming to have thermal comfort, yet prefer the environment to be cooler. Since majority voted in the negative side of the scale, it is evident that proper steps are required to reduce the indoor air temperature of these non –air conditioned in patient wards.

4.2.2.2 Votes regarding Relative Humidity:

Votes regarding the sensation, comfort and preference of relative humidity are analyzed and discussed in the following sub sections.

4.2.2.2.1 Sensation regarding relative humidity:

To judge the situation regarding relative humidity, patients were asked to vote on their humidity sensation, which are plotted in fig-4.13. Among the 400 responses, 51.25% (205) indicate their indoor humidity level as ‘slightly humid’ [+1] and 1.50% (6) voted it as ‘humid’ [+2] while 47.25% (189) voted ‘just right’ [0]. Total 98.5% respondents voted for the central three categories, having a mean vote of 0.542, which lie between the central categories of perfect [0] and ‘slightly humid’ [+1]. Thus the relative humidity sensation of the patients during warm humid periods can be considered to be within the acceptable range.

Range of Indoor relative humidity	65-86%

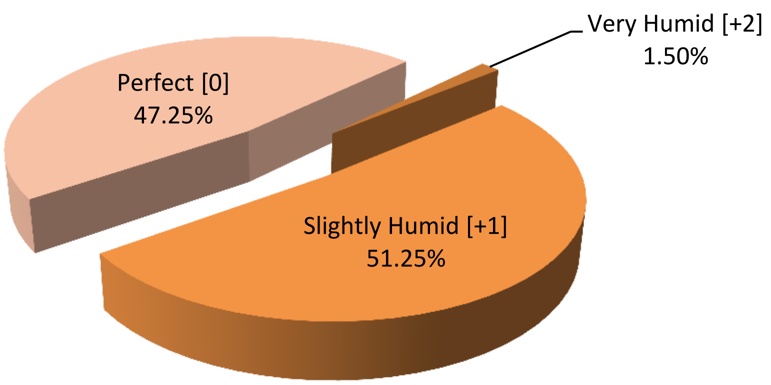


Figure 4.13: Vote distributions (in percentage) of ‘sensation’ on relative humidity

4.2.2.2.2 Comfort votes on relative humidity:

To cross check the sensation votes of patients regarding relative humidity, comfort votes on relative humidity were also obtained, which is illustrated in fig 4.14. The figure revealed that 50.25% (201) of the votes reveal the indoor environment as 'slightly uncomfortable' [-1] and 1.5% (6) as 'uncomfortable' [-2] while 48.25% (193) of them indicate a vote of 'slightly comfortable' [1]. Therefore 98.50% responses reveal the comfort condition in terms of relative humidity, within the centrally acceptable range (-1, 0, +1). Similar to 98.48% responses, who voted their sensation regarding relative humidity within acceptable range, 98.50% also voted the current condition is within their acceptable range of comfort as well.

Range of Indoor relative humidity	65-86%

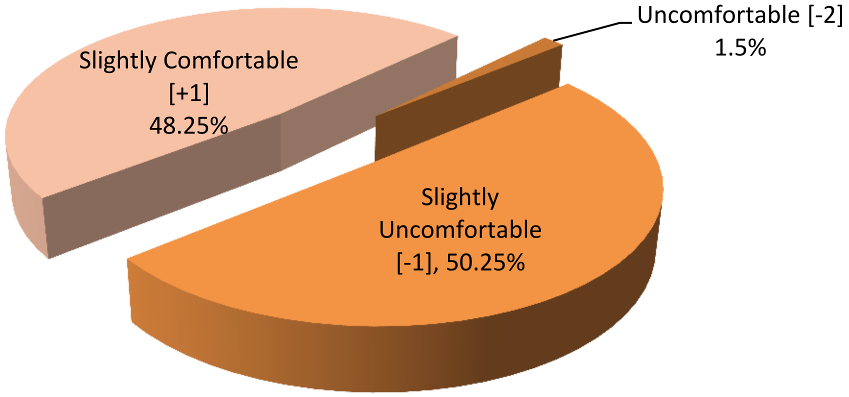


Figure 4.14: Comfort voting regarding relative humiditity

4.2.2.2.3 Preference votes on relative humidity:

In fig 4.15, 98.50% of the 400 responses votes for indoor relative humidity sensation within the acceptable range (-1, 0, +1). But when their preferences regarding relative humidity of the environment were enquired, 52% of the responses show the need to be in a drier environment. Among them 50.5% (202) of the votes prefer a 'slightly drier' (-1), 1.5% (6) prefer a 'much drier' (-2), while 48% (192) votes prefer 'no change' (0), under the current conditions, where the relative humidity range was 65%-86%.

Results regarding votes on relative humidity revealed that patient were not clear about effect of humidity on their comfort, or preferences compared, to their clearer consciousness and understanding, regarding air temperature's effect, on the same parameters (Section 4.2.2.1).

Range of Indoor relative humidity	65-86%

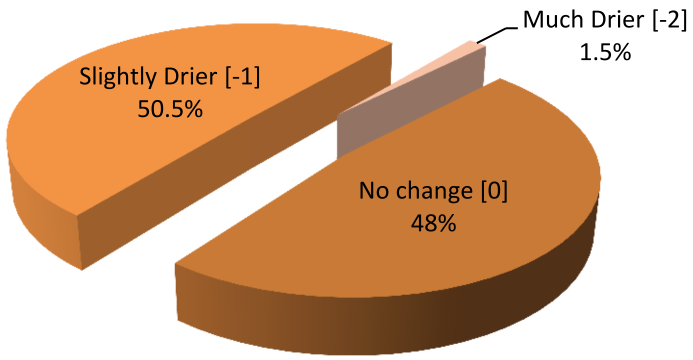


Figure 4.15: Distribution of preference Vote on relative humidity

4.2.2.3 Votes on air velocity

Votes regarding the sensation, comfort and preference of air velocity are analyzed and discussed in this sub section.

4.2.2.3.1 Vote distribution on air velocity scale:

Among the 400 responses, 32.5% (130) votes indicate the current air velocity to be within their respective in patient wards as 'slightly still' (-1) while 51.25% (205) show 'just right' (0), 15.25% (61) 'slightly breezy' (+1), leaving only 1% (4) to vote otherwise. So, about 99% of the patients voted within central three categories (-1, 0, +1) when the air velocity varied between 0.05-1.85 m/s. The mean vote was -0.15 which indicates that that the patients perceive the air velocity between 'just right' [0] and 'slightly still' [-1]. Orientation of wards, position of winds and presence of ceiling fans influenced their responses.

Range of Indoor air velocity	0.05-1.85 m/s

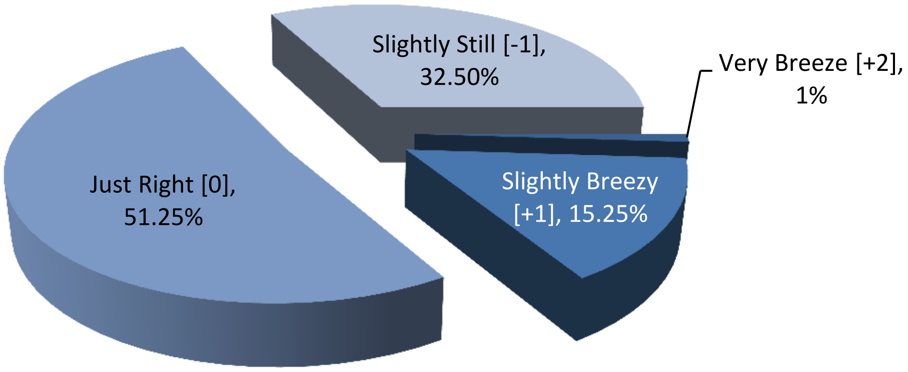


Figure 4.16: Distribution of sensation vote on air velocity

Among the 282 responses from the patients of wards, only 29.43% (83 responses) voted the air velocity inside the wards as ‘slightly still [-1] whereas 54.97% (155) voted for ‘Just right’ [0], 14.18% (40) voted for ‘Slightly Breezy’ [+1] and 1.42% (4 responses) voted for ‘Very breezy’ [+2]. But from the 118 responses of patients of west wards, 39.83% (47) voted for ‘Slightly Still’ [-1] whereas 42.37% (50) voted for ‘Just right’ [0] and 17.80% (21) voted for ‘Slightly breezy’ [+1]. These findings indicate that patients, from the wards with openings at the east sides, perceived their indoor environment more airy compared to the patients from wards at the west side.

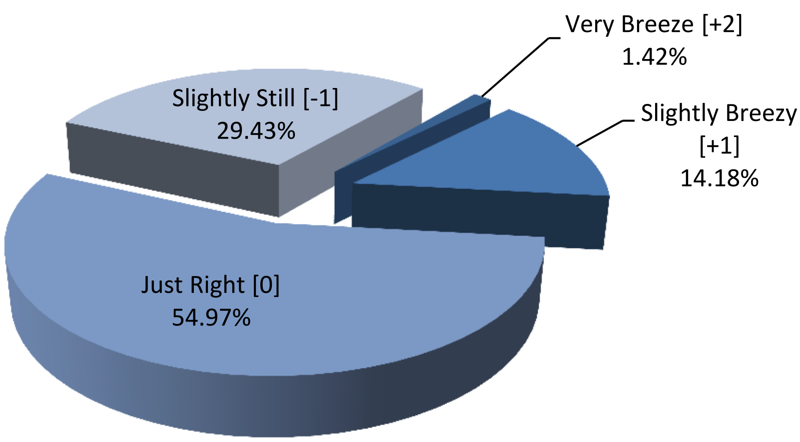


Figure 4.16(a): Distribution of sensation vote on air velocity (East side)

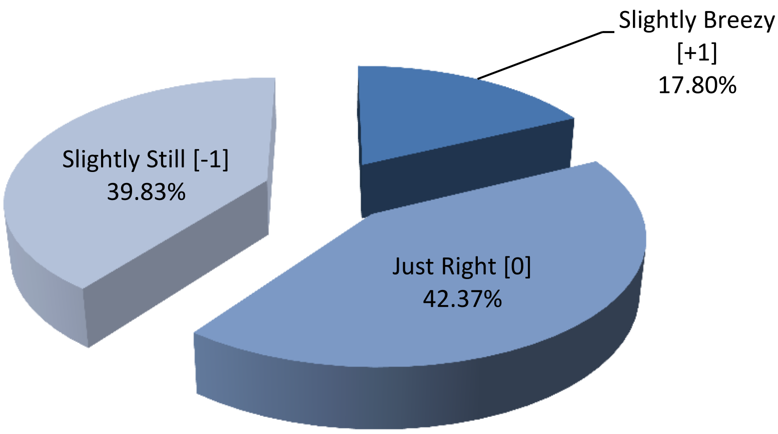


Figure 4.16(b): Distribution of sensation vote on air velocity (West Side)

4.2.2.3.2 Comfort votes on air velocity

When patients comfort votes were obtained, to cross check patient's sensation scale regarding the indoor air velocity, it was found that 67.25% of the respondents felt 'slightly comfortable' (+1) while 32.75% of them felt it 'slightly uncomfortable' (-1). Similar to the 99% respondents that voted on their sensation, regarding air velocity within wards within the centrally acceptable range (-1, 0, +1), 100% of them place their comfort vote within the acceptable range. It is assumed that, low activity level and the constant usage of ceiling fan for 24hrs influenced the respondent's sense of comfort positively, even though the environment was quite humid. No particular differences can be identified from patient's comfort votes from wards of both sides.

Range of Indoor air velocity	0.05-1.85 m/s

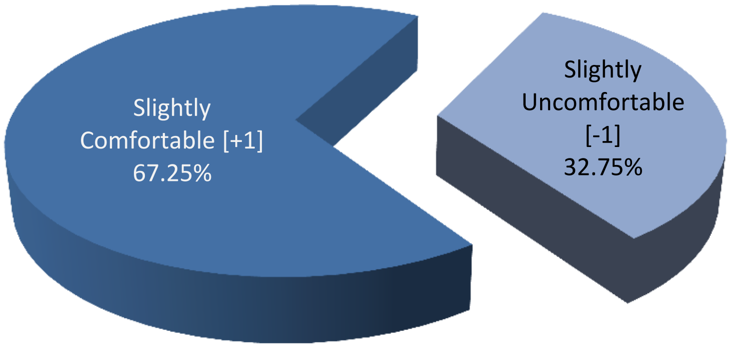


Figure 4.17: Comfort voting regarding air velocity

4.2.2.3.3 Preference regarding air velocity

Although 99% and 100% respondents cast their votes regarding sensation and comfort of air velocity within acceptable range, majority of the respondent (73.25%, 293 responses) indicated for 'more ventilation (+1) within their inpatient wards, while only 26.75% (107 responses) gave a 'no change' (0) vote. This significant difference between sensation, comfort and preference votes is a contradiction, but many earlier researches have already revealed similar situation. (Section 2.1.3.3.3)

Range of Indoor air velocity	0.05-1.85 m/s

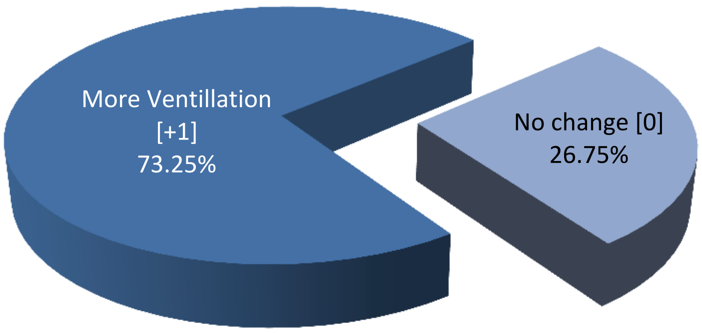


Figure 4.18: Vote distributions (in percentage) of preference on air velocity

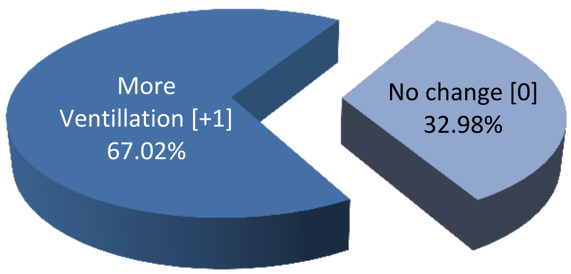


Figure 4.18(a): Vote distributions (in percentage) of preference on air velocity (East side)

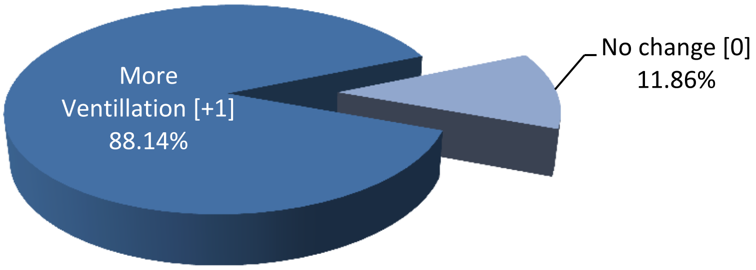


Figure 4.18(b): Vote distributions (in percentage) of preference on air velocity (West side)

Fig 4.18(a) and 4.18(b) shows that, about 88.13% responses (107 of 118 responses) from wards at the west side preferred 'more ventilation' [+1], whereas only 67.02% (189 of 282 responses) of the patient's responses from the wards of the east side preferred 'more ventilation'. It indicates that patients from the east side wards were more satisfied with the indoor velocity of the wards compared to the patients of the west side wards. Although the air temperature and humidity level was similar on both sides, due to air ventilation within the wards patients perception regarding the indoor environment was different, which support the studies of De Dear et al (1991) and Li et. al. (2010) (Section 2.1.3.3.3). Generally, people often open doors and windows for cooling when their environments are devoid of the scope of artificial ventilation, particularly when the air temperature is uncomfortably high.

4.2.3 Correlation among survey votes and environmental parameters

Correlation analysis among respondent's votes, and the corresponding simultaneously measured environmental variables, can indicate the strength of relationship between them. Table 4.1 presents the correlation matrix, showing the strength of relationships between the survey votes and the various indoor environmental variables (Section- 2.1.9). Correlation coefficient indicates existing linear associations between two variables, and its value ranges between -1 to +1, while the sign (+ve to –ve) of coefficient indicates the direction of the relationship. The absolute value indicates the strength of the relationship, and the larger the absolute value, the stronger is the relationship. As these variables are considered as ordinal variables, Spearman's rho correlation analysis (Table 4.1) was chosen for analysis (Maanen, 1989) (Black, 2002).

Table 4.1: Correlation matrix showing relationship between different variable

Correlations

			Thermal_Sensation_Vote	Thermal_preference	Sensation_regarding_RH	Preference_regarding_RH	Sensation_Votes_regarding_air_velocity	Preference_regarding_air_velocity	Temperature	Humidity	Air_Velocity
Spearman's rho	Thermal_Sensation_Vote	Correlation Coefficient	1.000	-.750**	.606**	-.590**	-.318**	.411**	.717**	-.604**	-.085
		Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000	.000	.091
		N	400	400	400	400	400	400	400	400	400
	Thermal_preference	Correlation Coefficient	-.750**	1.000	-.467**	.468**	.198**	-.295**	-.618**	.517**	.045
		Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000	.000	.374
		N	400	400	400	400	400	400	400	400	400
	Sensation_regarding_RH	Correlation Coefficient	.606**	-.467**	1.000	-.946**	-.322**	.291**	.402**	-.291**	-.043
		Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	.000	.387
		N	400	400	400	400	400	400	400	400	400
	Preference_regarding_RH	Correlation Coefficient	-.590**	.468**	-.946**	1.000	.312**	-.326**	-.380**	.267**	.078
		Sig. (2-tailed)	.000	.000	.000	.	.000	.000	.000	.000	.120
		N	400	400	400	400	400	400	400	400	400
	Sensation_Votes_regarding_air_velocity	Correlation Coefficient	-.318**	.198**	-.322**	.312**	1.000	-.319**	-.166**	.101*	.354**
		Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.001	.044	.000
		N	400	400	400	400	400	400	400	400	400
	Preference_regarding_air_velocity	Correlation Coefficient	.411**	-.295**	.291**	-.326**	-.319**	1.000	.286**	-.250**	-.486**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.000	.000	.000
		N	400	400	400	400	400	400	400	400	400
	Temperature	Correlation Coefficient	.717**	-.618**	.402**	-.380**	-.166**	.286**	1.000	-.804**	-.070
		Sig. (2-tailed)	.000	.000	.000	.000	.001	.000	.	.000	.160
		N	400	400	400	400	400	400	400	400	400
	Humidity	Correlation Coefficient	-.604**	.517**	-.291**	.267**	.101*	-.250**	-.804**	1.000	.023
		Sig. (2-tailed)	.000	.000	.000	.000	.044	.000	.000	.	.648
		N	400	400	400	400	400	400	400	400	400
	Air_Velocity	Correlation Coefficient	-.085	.045	-.043	.078	.354**	-.486**	-.070	.023	1.000
		Sig. (2-tailed)	.091	.374	.387	.120	.000	.000	.160	.648	.
		N	400	400	400	400	400	400	400	400	400

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

*. Correlation is significant at the 0.05 level (2-tailed).

The strongest positive correlation (+0.717) was observed between thermal sensation vote (ASHRAE scale) and indoor air temperature, which means the thermal sensation votes of the patients are highly dependent on the indoor air temperature. (Table 4.1). Meanwhile the lowest positive correlation is found, between sensation regarding air velocity and indoor humidity level (+0.101), which implies that people might not be sensitive enough to correlate indoor humidity level perception and sensation regarding air velocity.

Similarly, the negative correlation (-0.946) between sensation, regarding relative humidity, and its preference of relative humidity, which was the highest negative correlation, implies that respondents prefer drier indoors, compared to humid environment. The lowest negative correlation (-0.166) sensation, regarding air velocity and indoor air temperature level, reveals that air temperature has little to no impact, on the patient's sensation of air velocity inside the wards. It may be noted that, all the sensation votes were negatively correlated with their respective preference votes. For example when the patients voted their thermal sensation as slightly hot [+1], they preferred the indoor air temperature to be slightly cooler [-1]. Thermal sensation correlated positively with indoor relative humidity (+0.600), implying that the humidity of air did not directly affect the body's heat gain or loss. However, it determined the evaporative capacity of the air, and hence the cooling efficiency of sweating.

One of the most commonly used methods by thermal comfort researchers today, is to compare the measurements of the indoor environmental conditions, with all these votes to establish a trend between thermal comfort and these variables (McCartney & Humphreys, 2002) (Bordass et. al., 2011). Correlations between responses of 'sensation' for any environmental variable, and its corresponding measured environmental variables, help to understand respondent's sensitiveness towards that variable. In order to study these trends, the 400 responses were plotted in a scatter plot diagram; with their simultaneous environmental measurements .The slope of this diagram reveals the relationship between these two particular variables.

The following correlations were investigated to establish the relationship between 'sensation' and corresponding 'variables' of the 3 measured environmental variables (air temperature, relative humidity and air velocity) which will be discussed in following sub sections.

a. Thermal sensation votes and mean air temperature
b. Relative humidity sensation votes and mean relative humidity
c. Air velocity sensation votes and mean air velocity

4.2.3.1 Correlation between thermal sensation votes and mean air temperature

Thermal Sensation Votes (TSV) and its concurrent mean air temperature, measured during the survey period, are plotted in a scatter-plotter diagram (Fig 4.19). It shows a positive linear relationship between the two variables, whereas the value of 'R^2' (0.5649) indicates quite a strong relationship. So the higher the air temperature, the higher the thermal sensations vote (TSV). When the mean air temperature is 28.95 ºC, the TSV is 'Slightly cold' [-1], and when the temperature increases to 33.45 ºC, the thermal sensation vote indicates the 'hot' [+2] condition. The results are consistent with finding of previous researches regarding this trend.

Range of measured indoor Air temperature	28.95-33.45^{0}C

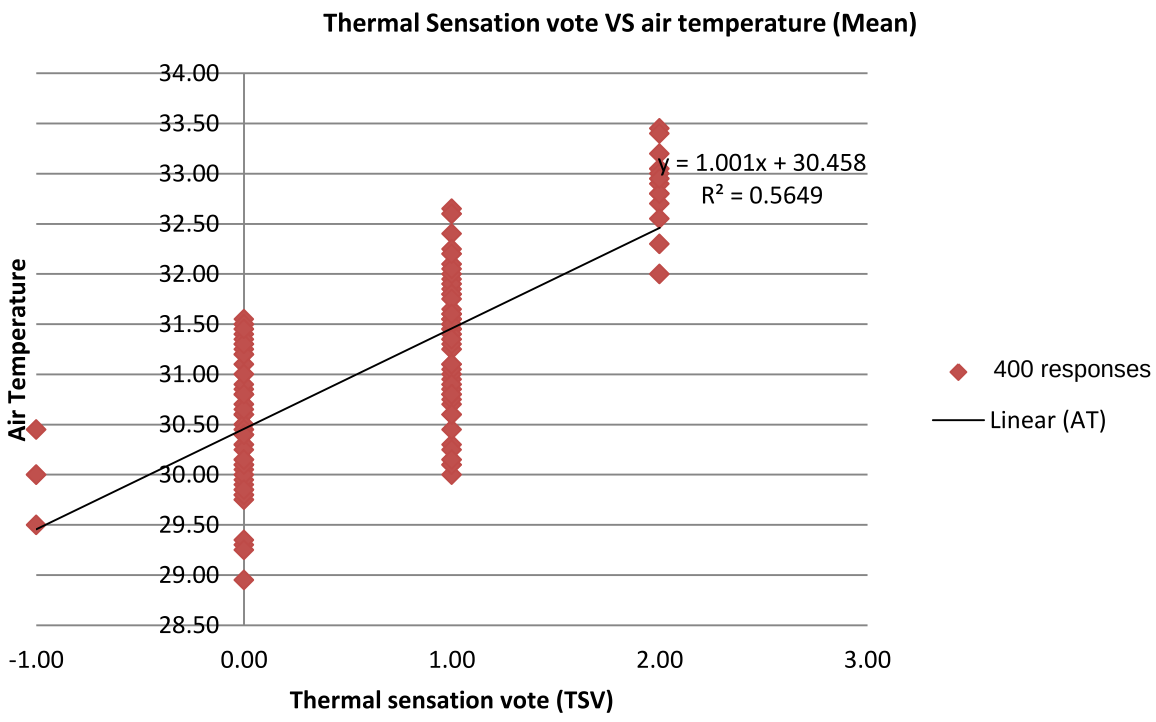


Figure 4.19: Correlation between 'thermal sensation votes' and air temperature (Mean)

4.2.3.2 Correlation between humidity sensation votes and mean relative humidity

Similarly, the relative humidity sensation votes and the mean measured relative humidity (mean) are plotted in Fig 4.20, and it indicated a slightly negative linear relationship between them, whereas the value of 'R^2' (0.1202) indicates a weak relationship between them. From the distribution of votes it can be seen that, the respondents were not consistently clear about their sensation regarding relative humidity, when compared to their sensation to air temperature reported in the last subsection. Presence of air movement (openings, ceiling fan etc.) is thought to have played an important role in causing this confusion.

Range of measured indoor relative humidity	65-86%

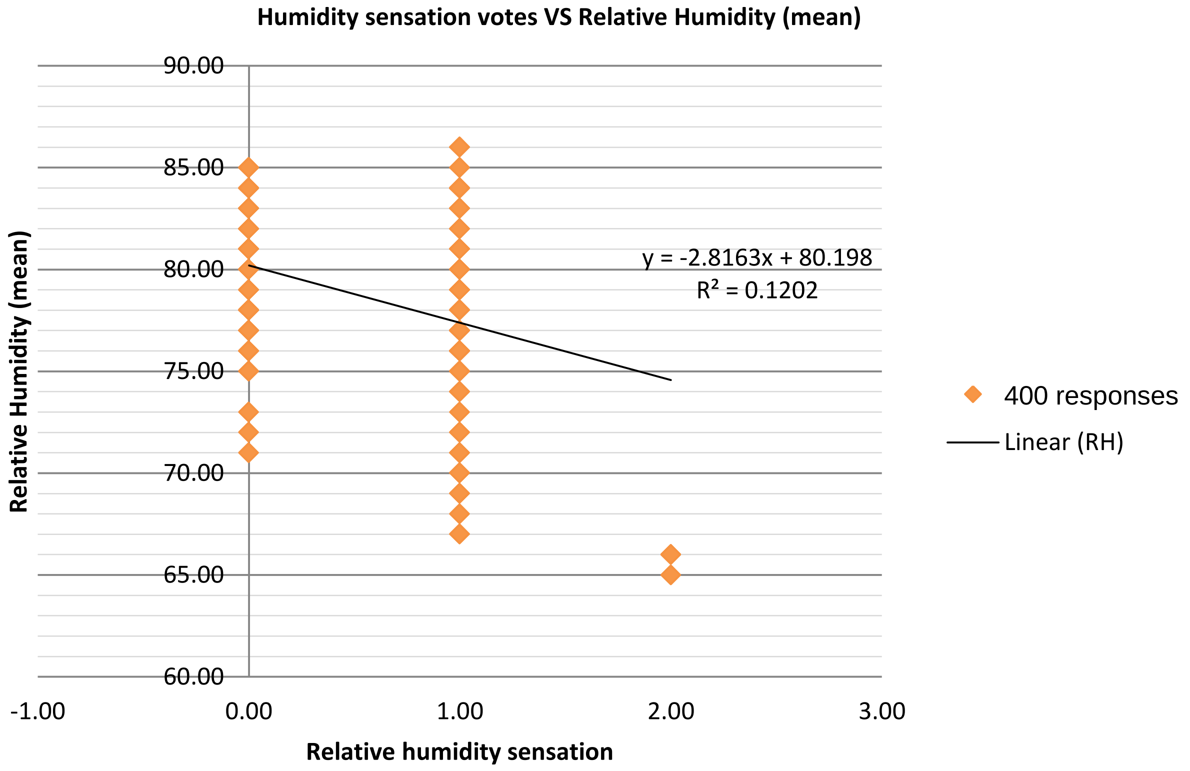


Figure 4.20: Correlation between 'humidity sensation votes' and relative humidity (Mean)

4.2.3.3 Correlation between air velocity sensation votes and mean air velocity

Fig 4.21 shows the correlation between air velocity 'sensation' votes and mean measured air velocity. The value of 'R^2' (0.1176) indicates a slightly positive linear relationship between these, similar to the relationship between relative humidity sensation votes and measured mean relative humidity.

Range of measured Indoor air velocity	0.05-1.85 m/s

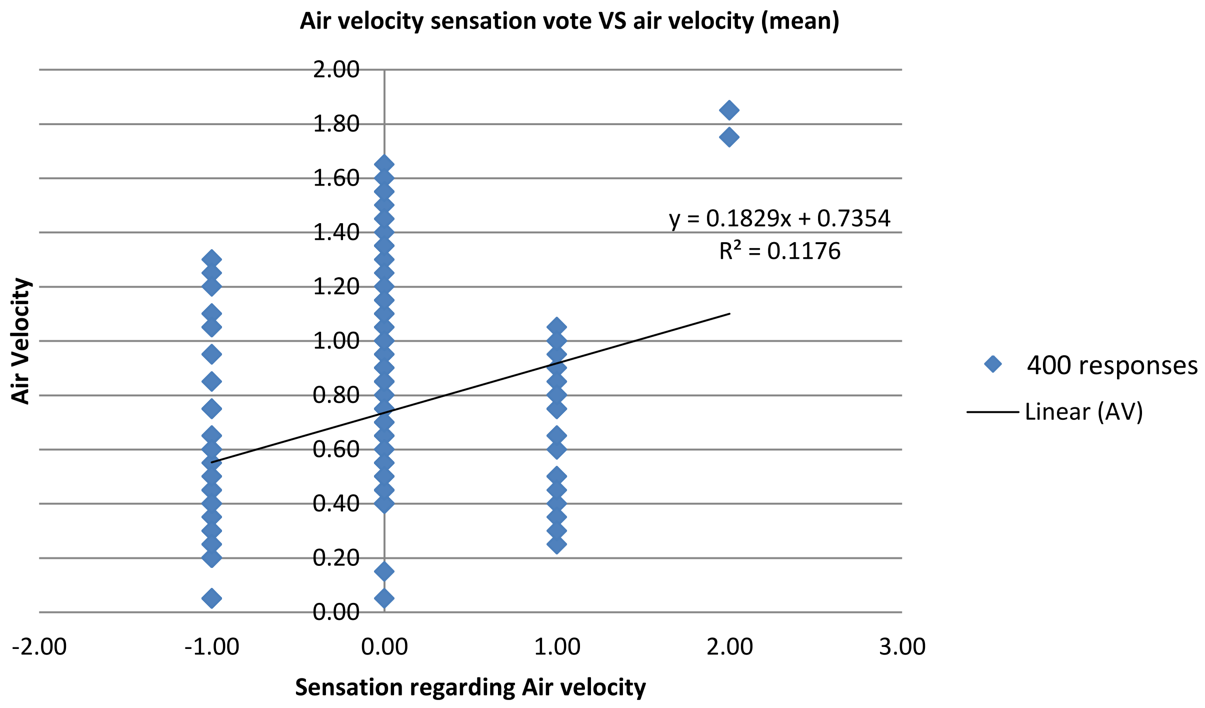


Figure 4.21: Correlation between 'air velocity sensation votes' and air velocity (Mean)

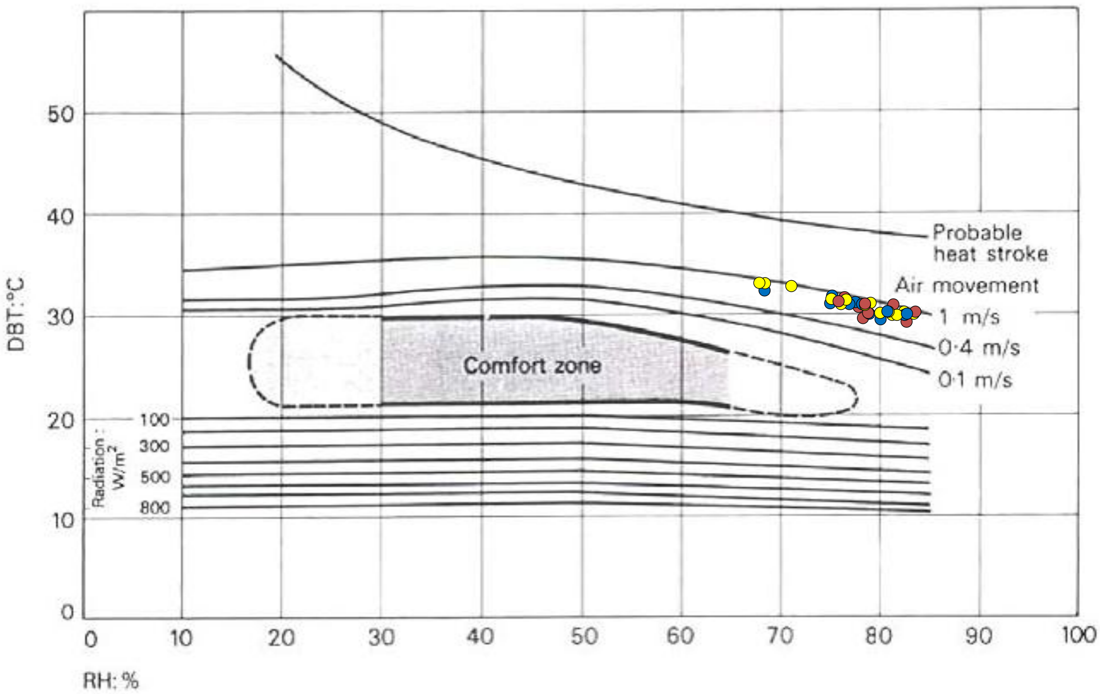
4.3 Proposed Comfort Parameters and Comfort Zone

The findings of this study were compared to the established comfort studies and comfort zones, discussed previously in Chapter-2: Section A.

4.3.1 Comparison with established comfort zone

According to Olgyay's Bioclimatic chart, comfort zone shifts upwards with air velocity and downwards with radiation. To investigate whether the results of this research agree with Olgyay's classic findings and its extent, the results were plotted on to the Bioclimatic chart (Figure 4.22).

Fig 4.22 indicates that many of the respondents have voted that they were in a 'comfortable' situation, even though the maximum number of conditions did not fit in the Olgyay's comfort zone, both for temperature and relative humidity levels. It was obvious, that the context of Olgyay's study differs significantly from this study. Adaptation and acclimatization are responsible for this deviation, as mentioned previously by researchers (Chapter 2: Section A) working in the climatic context of Bangladesh.



- Surgery Dept. (General Surgery and Urology)
- Surgery Dept. (Orthopedics, Eye, ENT)
- Medicine Dept. (General Medicine)

Figure 4.22: Comparison with Olgyay's comfort zone (Olgyay, 1973)

4.3.2 Compare with adapted comfort zone

The results of this survey were plotted on the adapted Bioclimatic chart, which was specifically prescribed for Dhaka (Mallick, 1994), to investigate the extent to which this survey agrees with that chart. Fig 4.23 show that, the results of this survey agreed with the adapted Bioclimatic chart to a great extent, and it had a great impact on the comfort ranges of the respondents.

When the measured environmental conditions (air temperature and relative humidity measured during the field investigation), were plotted on the adapted Bioclimatic Chart, it showed that all the measured conditions of the in-patient wards were within the comfort zone.

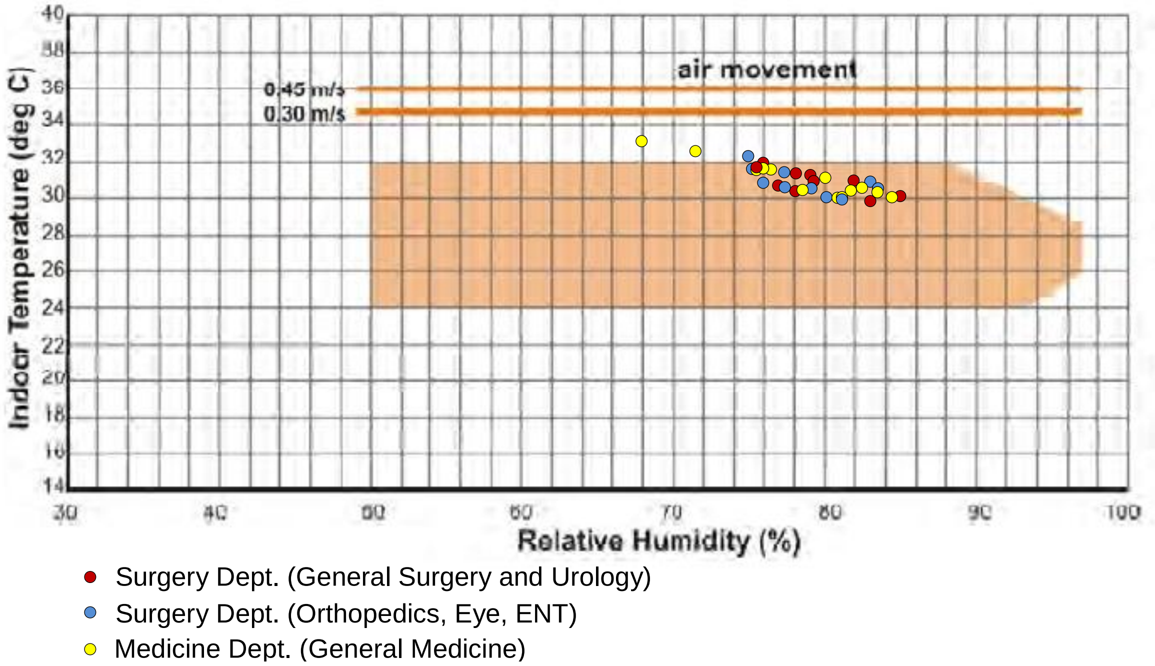


Figure 4.23: Comparison with adapted summer comfort zone for Dhaka, Bangladesh (Mallick, 1994)

However 54.75% of the respondents of this survey (Fig 4.4), did not accept the thermal conditions of the in-patient wards, which followed the thermal expectation and acceptability of residents. The study of the adapted summer comfort zone was conducted for residences, with occupants engaged in multiple activities and sound in health. The occupancy load in wards (patients and guardians), and limited availability of adaptation measures (for example limited openings, low activity level, posture, etc.) compared to residences may have played a role in placing the large number of unacceptability votes.

It is evident that standards of similar contexts are needed to establish appropriate comfort zones and the setting of contextual temperature standards that can contribute to the greater acceptability of environmental conditions for in-patient wards..

4.3.3 Identifying the Neutral condition

Comfort zone is where 80% of the subjects would express comfortable sensation regarding environmental parameters which is within the range of three central voting categories (vote= -1, 0, +1) whereas all other votes indicated discomfort (de Dear and Brager, 2002).

Neutral temperature is the temperature at which most people vote within the neutral• category of the sensation scale (the central category of seven-point ASHRAE scale). In this section, all the data gathered through questionnaire survey will be analyzed to generate a temperature value, where this respondent population would feel thermally 'neutral'.

4.3.3.1 Identifying 'neutral' air temperature

The 'neutral' air temperature for the patients occupying in-patients wards of Dhaka, during the monsoon period was identified through a scatter plot diagram of thermal sensation votes (TSV) of respondents, against their corresponding measured air temperature.

Range of measured indoor Air temperature	28.95-33.45^{0}C

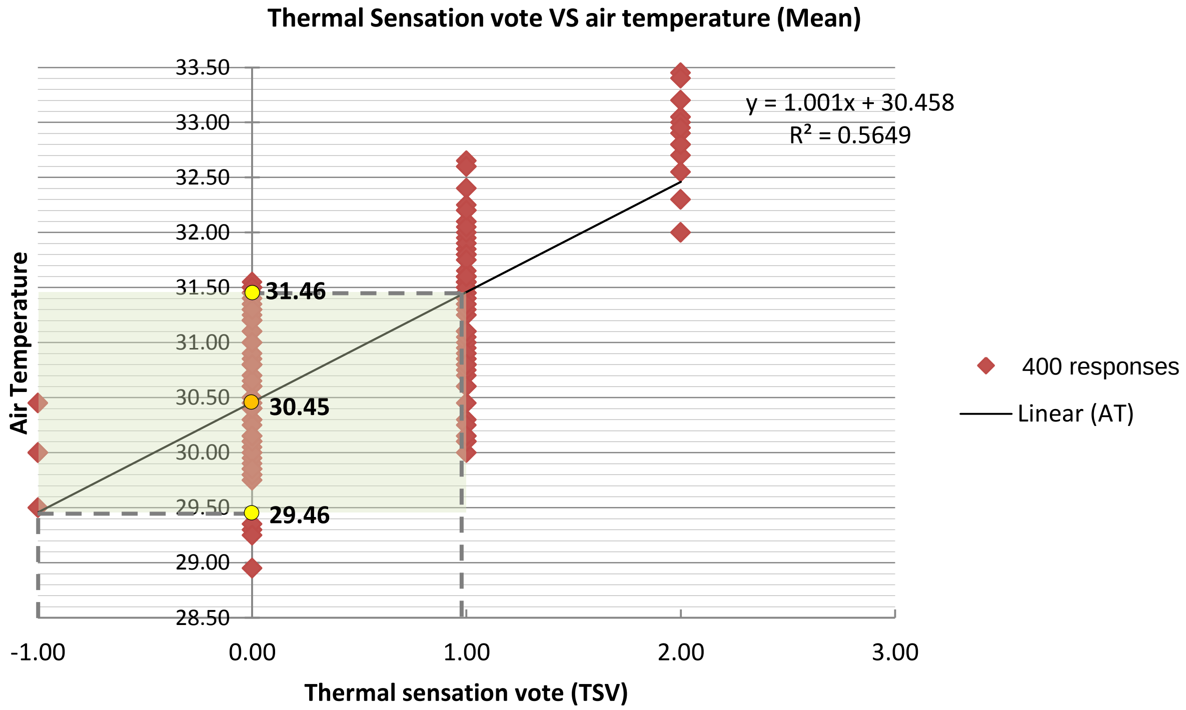


Figure 4.24: Identification of 'neutral' temperature

From Fig 4.24, the air temperature range perceived as 'comfortable' or 'acceptable' was identified from the temperature range, between the two lines of votes of 'slightly hot' [+1] and 'slightly cool' [-1], which was 29.46 ºC to 31.46 ºC. The intersection of the Thermal sensation votes and mean air temperature slope with the '0' TSV, has been identified as the 'neutral' temperature, which was found to be 30.45 ºC, where the thermal sensation is 'just right'.

4.3.3.2 Identifying neutral relative humidity

In a similar way, the relative humidity sensation was plotted with the measured mean relative humidity (Fig 4.25), and through the scatter plot diagram the relationship between these two variables was found and the relative humidity range that can be perceived by the respondents as 'comfortable', was identified as well.

Range of measured indoor relative humidity	65-86%

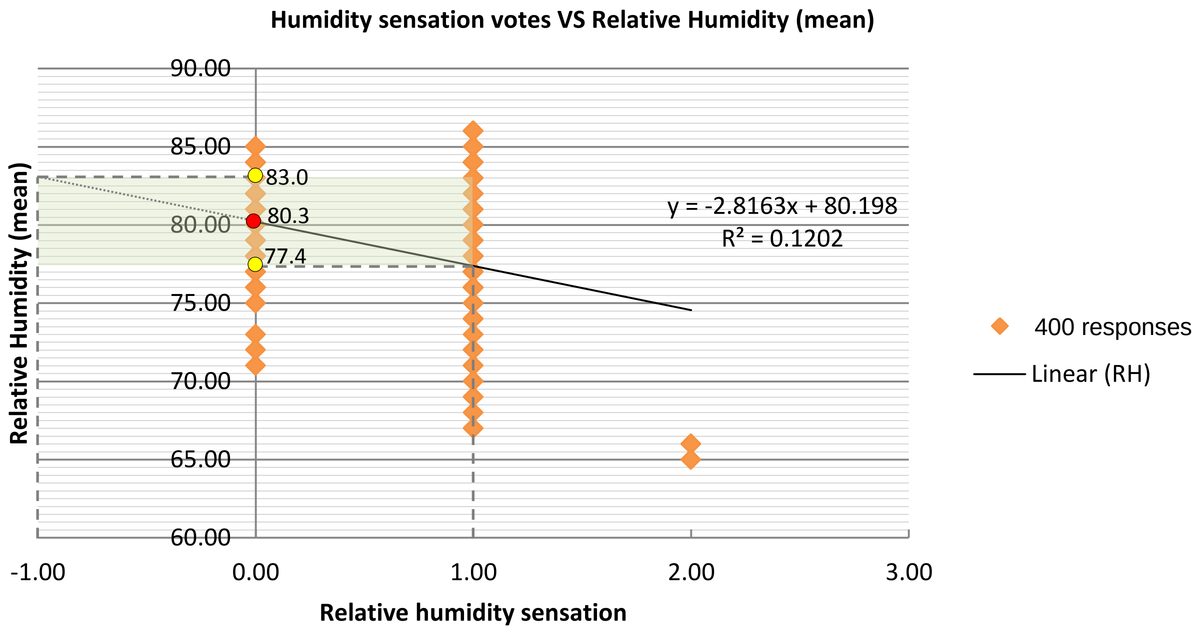


Figure 4.25: Identification of 'neutral' relative humidity

Fig 4.25 shows that, respondents voted their 'sensation' as acceptable [-1 to +1] for the relative humidity range of 77.4% to 83%. The 'neutral' relative humidity value is 80.3%, where the respondent's voted sensation as 'just right' (during monsoon period).

4.3.4 Proposed comfort parameters

If the indoor air temperature of about 30.45ºC and relative humidity of about 80.3% can be maintained in non-air conditioned in-patient wards, along with the mean air velocity of 0.95 m/s (during field investigation, air velocity range was 0.05 - 1.85 m/s), these combination of thermal conditions (air temperature, relative humidity and air velocity) would be perceived as 'comfortable', by most of the patients of inpatient hospital wards in Dhaka during the warm humid (monsoon) period. The results agree to a large extent to previous research on thermal comfort conducted in this climatic context (Chapter 2, Section A).

4.3.5 Calculation of 'preferred' temperature and 'preferred' relative humidity

To cross check the thermal comfort zone found in the previous section, a separate correlation analysis was done between preference votes regarding air temperature and relative humidity, against mean indoor air temperature and mean relative humidity respectively that were collected simultaneously, during the questionnaire survey.

4.3.5.1 Preferred air temperature

According to ASHRAE (1992), thermal comfort can be defined as a condition where people prefer neither warmer nor cooler conditions. Table 4.2 shows the relation between thermal 'sensation' vote and thermal 'preference' votes of the surveyed patients.

Table 4.2: Distribution on 'preference vote' on 'thermal sensation vote'

		Preference of Air temperature										
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	Total	%	Total	%
Thermal Sensation	**3**	0	0	0	0	0	0	0	0	0	**34**	**8.5**
	2	0	28	6	0	0	0	0	34	8.5		
	1	0	0	191	0	0	0	0	191	47.75	**366**	**91.5**
	0	0	0	72	95	0	0	0	167	41.75		
	-1	0	0	0	2	6	0	0	8	2		
	-2	0	0	0	0	0	0	0	0	0	0	0
	-3	0	0	0	0	0	0	0	0	0		
	Total	0	28	269	97	6	0	0	400	**100**		
	%	0	7	67.25	24.25	1.5	0	0	**100**			

About 95 responses (23.75%) out of 400, voted for both 'neutral' sensation [0] and 'no change' [0]. It reveals that the patients, who voted for 'neutral' sensation (ASHRAE scale 0) not always choose 'no change', when they were asked about 'preferred thermal condition'. 72 respondents out of 167 (43.12%), who felt 'neutral' [0] sensation, voted for 'cooler' [-1] environment, whereas 95 of them (about 56.88%) wanted 'no change' in their environment. It also indicates that respondents that feel 'neutral' were not always satisfied with their thermal condition. Again, the ones who were satisfied (prefer 'no change') with their environment, did not all have 'neutral' thermal sensation [0]. These findings prove that acceptable thermal sensations do not always correlate to people's preferred thermal state.

366 of these responses vote the air temperature sensation within the acceptable range [-1 to +1]. Only 97 responses (26.5%) among them indicated 'no change' [0], whereas about 263 responses (71.85%) were for a 'cooler' [-1 to -2] environment. Only 6 responses (1.65%)

wanted a 'warmer' environment [+1]. Again, 8.5%of the total responses (34 responses) indicated the air temperature sensation as 'hot' [+2] wanting 'cooler' [-1 to -2] environment.

Range of measured indoor Air temperature	28.95-33.45^{0}C

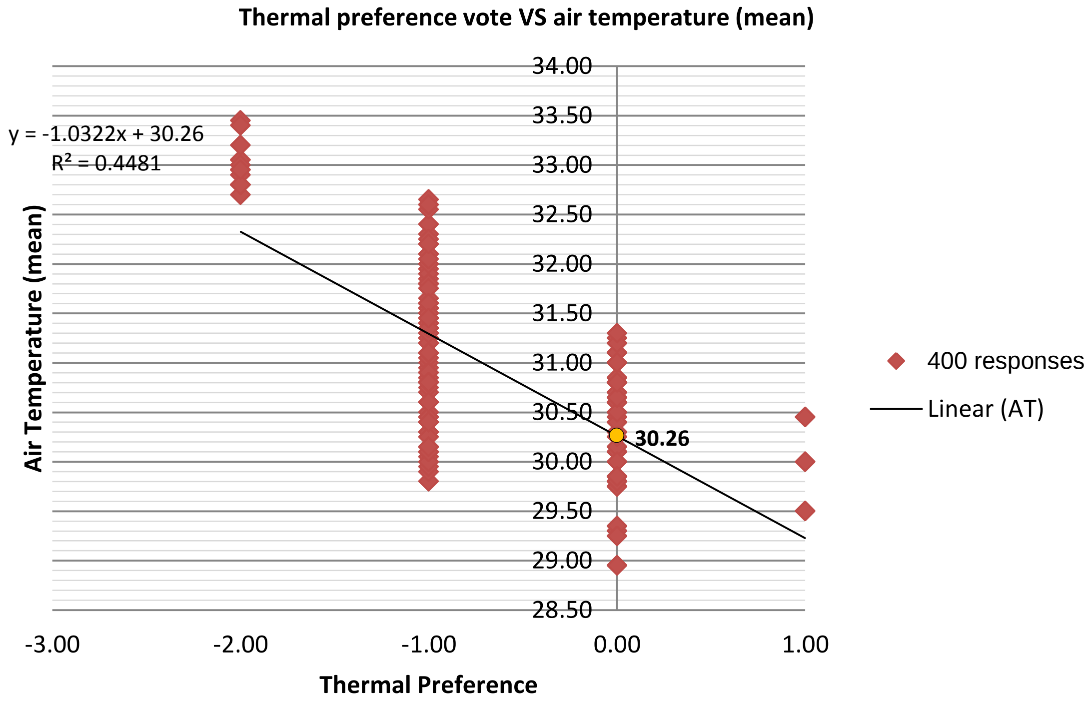


Figure 4.26: Identification of 'preferred' air temperature

The thermal 'preferences' votes of 400 respondents against their respective recorded mean air temperature were plot in Fig 4.26, which reveals a positive linear relationship and the value of 'R^2' (0.4481) indicates quite a strong relationship between these two variables. When air temperature increases, patients prefer cooler environment and when air temperature decreases, they want warmer environment. The 'preferred temperature' means the temperature point where they want neither 'warmer', nor even 'cooler' temperatures. The line of correlation intersects the line of 'no change' [0] (fig 4.26) at the temperature of about 30.26 ºC, which can be identified as 'preferred' temperature for the target population.

4.3.5.2 Preferred relative humidity

The relationship between relative humidity 'preference' and relative humidity sensation' is shown in the Table 4.3. Among the 400 responses, only 186 responses (46.5%) are votes for both 'neutral' sensation [0], and 'no change' [0], which indicates that 'neutral' sensation (ASHRAE scale 0) is not always 'no change' as respondent's votes were not the same for these two preferences. About 189 responses chose ‘neutral’ sensation but 186 of them (98.4%) preferred ‘no change’.

Table 4.3: Distribution on ‘preference vote’ on ‘sensation of relative humidity’

		Preference of Relative humidity										
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	Total	%	Total	%
Sensation regarding Relative Humidity	**3**	0	0	0	0	0	0	0	0	0		
	2	0	2	4	0	0	0	0	6	1.5		
	1	0	4	195	6	0	0	0	205	51.25	**394**	**98.5**
	0	0	0	3	186	0	0	0	189	47.25		
	-1	0	0	0	0	0	0	0	0	0		
	-2	0	0	0	0	0	0	0	0	0		
	-3	0	0	0	0	0	0	0	0	0		
	Total	0	6	202	192	0	0	0	**400**	**100**		
	%	0	1.5	50.5	48	0	0	0	**100**			

Table 4.3 shows that, a total of 394 responses (98.5%) voted their relative humidity sensation within the acceptable range [-1 to +1], but 51.27% of those responses (202 responses) preferred ‘drier’ environment whereas 48.73% (192 responses) preferred ‘no change’. Only 1.5% of the total responses (6 responses) voted the relative humidity sensation as ‘very humid’ [+2] and all of them preferred ‘drier’ environment.

Range of measured indoor relative humidity	65-86%

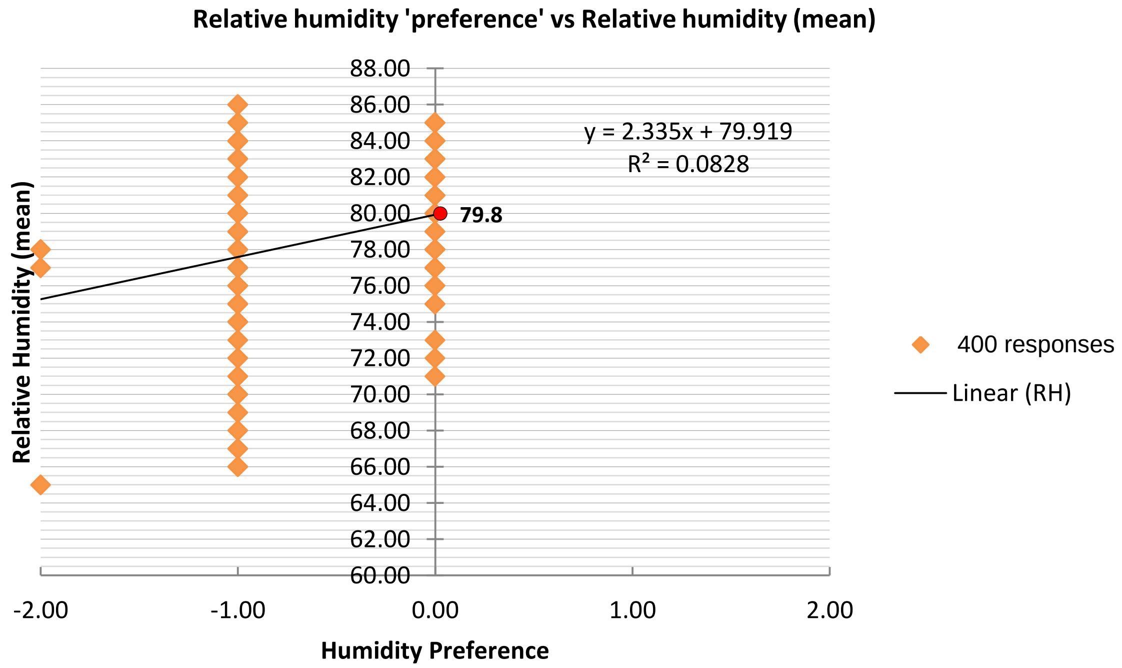


Figure 4.27: Identification of ‘preferred’ relative humidity

Fig 4.27 shows a plot of humidity 'preferences' against their respective relative humidity (Mean) which reveals a positive linear relationship between these two variables. The 'preferred' relative humidity means the relative humidity point where they want neither 'drier', nor even 'humid' environments. The line of correlation intersects the line of 'no change' [0] (Fig 4.27) at the relative humidity of about 79.8% that can be identified as 'preferred' relative humidity for the target population. But as the value of 'R^2' (0.0828) is very low, which indicates very weak relationship between the two variables.

This study has revealed that the 'preferred temperature' and 'preferred relative humidity' for the patients in inpatient hospital wards of Dhaka during warm humid season are 30.26 ºC and 79.8% respectively, when most patients will be satisfied with the environment under warm humid climates, and have no will the to change them. It may be noted here that both these values are close to but slightly lower than their respective 'neutral' that they themselves identified during the questionnaire survey (Section 4.3.3). The difference between preferred' and 'neutral' temperatures was 0.19^0C whereas the difference between 'preferred' relative humidity and its 'neutral' value in this study was only 0.5%.These findings are similar to the findings of de Dear and Brager (1997), where the difference between the 'preferred' and 'neutral' temperatures is minor, for the naturally ventilated buildings.

4.4 Summary

This chapter has focused on analyzing data that was obtained from the questionnaire survey, and the simultaneously measured environmental variables, during field investigation throughout the warm humid season (June-September). Through a systematic statistical analysis he objectives of this research have been fulfilled, and reported in this chapter. Also, going to airy spaces or verandah, changing level of clothing or cover, using hand fan, changing posture etc. are the most common adaptation measures that patients undertake in the wards to minimize their thermal discomfort. Some conclusions can be drawn up from these analyses, along with some future recommendations, regarding indoor thermal comfort requirements of patients in non-air-conditioned inpatient hospital wards of Dhaka during warm humid seasons, which will be discussed in the next chapter.

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CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Findings of the research

Achievements of the objectives

Recommendation

Limitations

Suggestions for future research

5.0 Introduction

This research is the first field study based investigation, which analyzes the indoor environment of non-air conditioned in-patient hospital wards in Dhaka, during warm humid periods. Through the analysis of both qualitative and quantitative aspects, the indoor thermal comfort ranges, along with acceptable environmental parameters for patients in non-air conditioned wards, were investigated and the findings and analysis have been presented in chapter-4. This final chapter will discuss the overall findings of this research, recommend some guidelines regarding the improvement of indoor thermal environment of in-patient wards, and identify some directions towards future scope of research in this field.

5.1 Findings of the research:

The research is based on field investigation of 200 patients in non-air conditioned inpatient wards through a questionnaire survey, and simultaneous measurement of environmental variables for the warm humid period (June-September, 2017), to analyze indoor thermal comfort conditions, and occupants' preference regarding these. The indoor environment was measured with calibrated digital instruments following ASHRAE protocols for field studies. Qualitative data was recorded in the field following the standard questionnaire format, from samples whose age was between 20-40 years, average clothing insulation was 0.24–0.5 clo and metabolic rate (1.0 Met) to keep the criteria similar for all the respondents.

This field survey, was conducted under conditions where the airflow was mainly generated by running ceiling fans, which is a common practice in Dhaka. To make the research more close to reality, this investigation was done in wards, where the ceiling fans were fully functional all the time, with average mean indoor air velocity of 0.9 m/s (range= 0.05 m/s to 1.85 m/s), and votes were taken considering this. This research followed both subjective and objective studies, to contribute to the knowledge of thermal comfort for non-air conditioned inpatient wards, and this section summarizes the major findings.

5.1.1 Findings regarding 'acceptability'

The research showed, 'neutral' temperature in non-air conditioned hospital wards, feel comfortable for a higher temperature range, compared to previous studies, for urban areas of Dhaka city. The findings agree with previous thermal studies of tropical regions, which have showed that in non-air conditioned spaces, people have wider range of acceptability to environmental conditions, compared to ASHRAE and ISO standards.

About half of the patients (54.75% of the responses) voted that the thermal conditions were 'not acceptable' (Figure 4.4), while 73.5% voted that these conditions didn't have any impact on their recovery (Figure 4.6). Yet, 94.5%, 98.5% and 100% patients voted the existing conditions of air temperature (Figure 4.11), relative humidity (Figure 4.14) and air velocity (Figure 4.17) respectively within their 'acceptable range' [+1 to -1] of comfort.

5.1.2 Findings regarding 'Sensation':

a. Air temperature:

Correlation analysis (Figure 4.24), of mean air temperature and their corresponding votes on ASHRAE scale, revealed a wide range for temperatures during the survey period (when air temperature was 28.95ºC to 33.45 ºC). From this analysis, the 'neutral temperature' for patients, wearing normal summer clothing in sedentary position (with air movement by ceiling fan, average 0.9 m/s), was plotted as 30.45 ºC. The acceptable temperature range, which was 29.46 ºC to 31.46 ºC with TSV in the central range (-1 to +1), reveals that patients had a wide comfort zone, as they were well adapted to their thermal environment.

According to ASHRAE (2004), votes that fall within the three central categories of the thermal sensation scale, are considered to be within the comfort range. In this research, only 8.5% votes were outside the -1 to +1 range, which expresses overall discomfort (Fig 4.10).

b. Relative Humidity:

The patients expressed comfort for the range of 77.4-83% (Figure 4.25), which is a narrow range of relative humidity levels, considering the air movement by ceiling fans. This research measured indoor humidity ranging from 65% to 86%, with mean indoor air velocity of 0.9 m/s during the survey period. This is contrary to previous research findings in urban contexts in indoor conditions, where results show that people have much higher relative humidity tolerances of up to 95%, this tolerance level varies with air movements (Mallick 1994).

c. Air velocity:

99% of the patients voted in the central three categories i.e. 'slightly still' [-1], 'just right' [0] and 'slightly breezy' [+1] (Figure 4.16), for measured mean indoor air velocity of 0.9 m/s. But majority of the respondents (73.25%) voted for more ventilation, whereas only 26.75% wanted 'No Change' (Fig 4.18). From the responses it is clear that, air movement is always welcomed in the wards.

5.1.3 Findings regarding 'Preference':

a. Air temperature:

The 'preferable temperature' for the patients was plotted as 30.26 ºC (Fig 4.26), which is only slightly lower (0.19^{0}C) than the plotted 'neutral temperature' of 30.45 ºC (Fig 4.24), and this finding is similar to the results of previous thermal comfort research in similar climatic contexts.

Among 366 patients, who voted the air temperature sensation to be within the acceptable range [-1 to +1], only 26.5% (97 respondents) wanted 'no change' [0], while 73.5% (269 responses) wanted cooler environment (Table 4.2). It proves that respondents, who were satisfied (preferring 'no change') with their environment, were not all having "neutral" [vote=0] thermal sensation. Again, a large percentage of them wanted their environment to be cooler. The results obtained are comparable with findings in previous studies of Feriadi, H. et al. (2003), Nyuk, H.W. et al. (2003), Busch, J. F. (1992) and Shahjahan, A. (2012) in Section A of Chapter-2.

b. Relative Humidity:

The preferred 'relative humidity' (79.8%) was found to be slightly lower (0.05%) than the identified 'neutral' relative humidity (80.3%) of the patients (Figure 4.27 and 4.25). Patients 'preferred' relative humidity close to their 'neutral' relative humidity, similar to 'neutral' and 'preferred' air temperature. Although higher relative humidity is considered uncomfortable in tropical climate, because air temperature remained lower than skin temperature and accompanied by constant air circulation within the wards during the warm humid period, patients were more tolerant of the humidity.

c. Air velocity:

Although 100% patients (Fig 4.17) voted their comfort condition regarding air velocity within the acceptable range [-1, 0, +1], yet majority (73.25%) of them voted for 'more ventilation' in their wards (Fig 4.18). This finding was similar to indications of previous research of de Dear, R. J. et al. (1991) and Li, B. et al. (2010). (See section 4.2.2.3.3)

5.1.4 Findings regarding 'Adaptation measures':

As patient's movement is often restricted inside wards, they had to adopt various means to maintain themselves in a comfortable state (Section 4.1.6). From the questionnaire survey, it was found that 'going to airy places' like a verandah, or near an open window, were the most common measures (41%) taken by patients against thermal discomfort. Other common adaptation measures like ‘changing level of clothing/cover’ (18%), ‘using hand fan’ (13%), ‘change posture’ (12%) etc. reveals that many patients prefer to adjust their comfort, without leaving their space as much as possible, due to health and mobility issues. As most of the time the openings (windows and doors) were kept fully open, and the ceiling fans were running at their full capacity, measures like ‘increase the speed of the fan’, or ‘opening window’ were not mentioned by patients as a measure to reduce thermal discomfort.

Previous adaptive comfort research have revealed that, when occupants have the freedom to modify the indoor environment, and to make necessary adjustments, to compensate for less-than comfortable thermal conditions, then these adaptive actions contribute in some positive ways, to a perception of higher level of thermal comfort. This is very similar to the findings of this research. But as the scope of adaptation is limited in hospital in-patient wards, compared to other type of buildings, where the occupants are more mobile, Figure 4.23 reveals the difference in expectations.

5.1.5 Findings regarding perceived impact on recovery:

Although it was assumed that the thermal discomfort, during the warm humid period, could have a negative effect on the health of the patients, only 26.5% patients actually thought this to be true. Due to slightly lower temperature, compared to the hot summer, and due to continuous exposure to ceiling fans, most of the patients considered the indoor environment comfortable, most of the time.

5.2 Achievements the objectives:

The objectives (given in section 1.3) of this study were achieved as given below.

Objective-1, where the existing thermal condition of non-air conditioned in-patient wards was inspected and compared to acceptable thermal standards, is discussed in Section 4.2.1. It revealed that the indoor thermal conditions during warm humid periods were out of the acceptable thermal standards most of the times.

Objective-2, where the understanding of patient’s thermal sensation, comfort and preference in the non-air conditioned in-patient wards were initiated, was discussed in section 4.2.2 and 4.3. The findings were also summarized in the section in section 5.1.2 and 5.1.3 of this chapter.

Objective-3 was discussed in section 4.3.4, which identified the combination of indoor thermal conditions, where the air temperature, relative humidity and mean air velocity were found to be 30.45ºC, 80.3% and 0.95 m/s respectively, which will be perceived as comfortable by most of the patients in the context of Dhaka during the warm humid periods.

Objective-4 was discussed in section 4.3.3 and 4.3.5. This study identified the 'Neutral' temperature and 'Neutral' relative humidity of the occupants are 30.45ºC and 80.3%, whereas their 'Preferred' temperature and 'Preferred' relative humidity are slightly lower, being 30.26 ºC and 79.8% respectively, during the warm humid periods.

5.3 Recommendations:

This research found that, thermal adversities encountered in warm humid season are quite well tolerated by the patients, due to adaptation and acclimatization. It is essential, to provide a thermally comfortable and healthy indoor environment to patients, for their smooth recovery.

The findings of this research have reconfirmed that sensation, comfort and preferences of this tropical country, is different from international standards (ASHRAE, ISO). Therefore, more attempts to develop a more relevant and contextual thermal comfort standard should be undertaken, that can accommodate different expectations, preferences and adaptation measures, for non-air conditioned spaces in Bangladesh.

Measurements of environmental variables revealed that indoor environment is highly influenced by the air movements. Designing an airy and well ventilated in-patient ward, by utilizing the outdoor environment should be of prime consideration, in this tropical country. Accurate openings for ventilation and positioning of ceiling fans should be considered as well.

Relevant thermal standards for indoor thermal conditions should be set on an urgent basis, according to the climatic condition of Dhaka. Preference of occupants should be given due consideration. The relevance of using international thermal standards needs to be re-examined, so that they are not set too high, causing thermal discomfort for tropical populations.

5.4 Limitations

This investigation was conducted under the following limitations.

1. Due to time constraints, this study concentrated only on the thermal conditions of the warm-humid periods, considering the adverse weather conditions during that time of the year.

2. Due to time constraints and for easy access to related data and resources, only the teaching hospitals of Dhaka were studied.
3. Due to unavailability of running teaching hospital of the same prototype in the similar microclimate of Dhaka, this study was only conducted on one hospital.
4. Due to time limits and lack of available samples only the inpatient wards with North-South orientation was studied.

5.5 Suggestions for future research:

After considering the limitations (Section 5.4) and, to strengthen and compliment this research, future research is recommended that could look further into the following issues.

(i) To have more comprehensive studies about indoor thermal conditions, and its relationship with outdoor changes, a year around investigation may be done on environmental parameters, of both indoor and outdoor conditions, following the methodology adapted in this research, leading to a more relevant and comprehensive standard.

(ii) To have a complete understanding of indoor thermal conditions, other case studies in similar micro climate contexts can be studied.

(iii) To determine the effects of air velocity, on the perception of thermal comfort, further comprehensive investigations are required.

(iv) To establish appropriate comfort standards for all over Bangladesh, further investigations should be conducted in the other climatic zones of the country, and for longer periods.

This research mainly investigated the thermal condition of non-air conditioned in-patient wards, patient’s sensation, comfort, preferences, their perceived impact on recovery, as well as adaptation and behavioural adjustments on thermal expectations in context of Dhaka, during the warm humid periods. The findings of this research have the potential to be used as the basis for further research and investigation, to study other aspects, and consequences of indoor thermal condition of non-air conditioned inpatient wards of Dhaka.

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APPENDICES

Appendix-01:

Insulating value of clothing elements
(Source: Based on ASHRAE 1985, from Auliciems and Szokolay 2007)

Men's Clothing Items		Clo		Women's Clothing Items		Clo
Underwear	Singlet	0.06		Underwear	Bra+panties	0.05
	T-Shirts	0.09			Half slip	0.13
	Briefs	0.05			Full slip	0.19
	Long, upper	0.35			Long, upper	0.35
	Long, lower	0.35			Long, lower	0.35
Shirt	Light, short sleeve	0.14		Blouse	Light	0.20
	Light, long sleeve	0.22			Heavy	0.29
	Heavy, short sleeve	0.25		Dress	Light	0.22
	Heavy, long sleeve +5% for tie or turtle-neck	0.29			Heavy	0.70
Vest	Light	0.15		Skirt	Light	0.10
	Heavy	0.29			Heavy	0.22
Trousers	Light	0.26		Slacks	Light	0.26
	Heavy	0.32			Heavy	0.44
Pullover	Light	0.20		Pullover	Light	0.17
	Heavy	0.37			Heavy	0.37
Jacket	Light	0.22		Jacket	Light	0.17
	Heavy	0.49			Heavy	0.37
Socks	Ankle length	0.04		Stockings	Any length	0.01
	Knee length	0.10			Panty-hose	0.01
Footwear	Sandals	0.02		Footwear	Sandals	0.02
	Shoes	0.04			Shoes	0.04
	Boots	0.08			Boots	0.08

Appendix-2

Air temperature profile of Dhaka city year 1950-2006 (Rashid, 2008)

Year	Variables	Pre-Monsoon			Monsoon				Post-mon		Winter			Ann
		Mar	Apr.	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
1950-1980	Mean max Temp ^{0}C	32.6	34.5	33.0	31.4	31.0	31.1	31.4	30.8	28.7	26.0	25.5	28.5	30.4
	Mean Min Temp ^{0}C	19.7	23.5	24.8	25.8	26.2	28.1	25.9	23.7	18.2	13.3	11.7	14.5	21.1
	Avg. Temp. ^{0}C	26.2	29.0	28.9	28.6	28.6	28.6	28.6	27.3	23.5	19.7	18.6	21.5	25.8
1981-1990	Mean max Temp ^{0}C	32.4	33.4	33.1	32.4	31.5	31.9	31.9	31.8	29.9	26.7	25.8	28.4	30.8
	Mean Min Temp ^{0}C	20.5	23.5	24.6	26.3	26.3	26.5	26.0	24.0	19.3	14.7	13.2	15.8	21.7
	Avg. Temp. ^{0}C	26.5	28.5	28.9	29.3	28.9	29.2	28.9	27.9	24.6	20.7	19.5	22.1	26.5
1991-2000	Mean max Temp ^{0}C	32.6	34.0	33.2	32.7	31.8	31.9	32.1	32.0	29.8	26.6	25.0	28.0	30.8
	Mean Min Temp ^{0}C	20.6	23.7	24.7	26.3	26.4	26.5	25.9	23.9	19.2	14.0	12.7	15.9	21.7
	Avg. Temp. ^{0}C	26.6	28.9	29.0	29.5	29.1	29.2	29.0	28.0	24.5	20.3	18.8	21.9	26.2
2002-2006	Mean max Temp ^{0}C	27.5	29.0	30.5	29.8	29.4	29.5	29.0	28.0	24.3	21.0	19.8	24.9	26.9
	Mean Min Temp ^{0}C	24.5	27.6	27.9	28.4	28.6	28.7	27.7	26.9	23.5	20.3	16.3	21.9	25.2
	Avg. Temp. ^{0}C	26.5	28.4	29.1	28.8	28.9	29.1	28.5	27.4	24.0	20.8	18.5	23.0	26.1

Apendix-03: Distribution of healthcare facilities of Bangladesh (1967-2012)

Year	Hospitals		Govt. Dispensaries	Beds in		No. of Medical College	
	Govt.	Private		Govt. Hospitals and Dispensaries	Private	Medical College	PG Medical Institute
1967	79	N/A	1374	17080	N/A	6	1
1968	89	N/A	1374	7193	N/A	7	1
1969	87	N/A	1374	7493	N/A	7	1
1970	88	N/A	1400	8387	N/A	7	1
1971	120	N/A	1450	9253	N/A	8	1
1972	130	N/A	1432	12656	N/A	8	1
1973	129	N/A	1348	12649	N/A	8	1
1974	129	N/A	1348	12649	N/A	8	1
1975	131	N/A	1722	15452	N/A	8	3
1976	131	N/A	1724	15473	N/A	8	3
1977	131	N/A	1752	15463	N/A	8	3
1978	388	36	1752	16853	2685	8	3
1979	405	36	1752	17494	2703	9	3
1980	510	39	1752	18957	3030	9	5
1981	512	164	1468	19021	4771	9	6
1982	544	164	1446	19136	4771	9	6
1983	560	164	1493	20286	4771	9	6
1984	568	264	1559	21870	4771	9	5
1985	596	264	1275	22874	4771	9	5
1986	600	264	1275	23306	4771	9	5
1987	608	267	1310	26575	6463	9	5
1988	608	267	1310	26871	6463	9	5
1989	608	267	1310	26913	N/A	9	5
1990	608	267	1310	N/A	N/A	9	5
1991	610	280	1318	27111	7242	10	5
1992	611	280	1362	27111	7242	13	5
1993	611	292	1397	27637	7643	13	5
1994	639	280	1397	28553	7247	13	6
1995	645	288	1397	29106	8025	13	6
1996	645	288	1362	29502	8025	13	5
1997	650	288	1397	30081	8025	13	6
1998	647	626	1397	30506	11371	24	5
1999	660	613	1397	31772	11521	13	N/A
2000	660	613	1397	32072	11371	13	N/A
2001	670	712	1397	22268	12239	13	N/A
2002	670	712	1397	32459	12239	13	5
2003	672	712	1397	33886	12239	13	N/A
2004	671	1005	1397	34550	16105	13	4
2005	671	1005	1397	34722	16105	13	4
2012	583	2966	N/A	41655	53448	N/A	N/A

Source: 1. Director General of Health Services (Health Information Unit), Ministry of Health and Population Control Statistical Yearbook 1984, 1999
2. Statistical Yearbook 2003, 2005, 2012

Appendix-04:

Recommended Indoor design conditions for Air conditioned Hospitals

Table 8.2.1: Inside Design Conditions of Some of Applications for Summer[a]

Sl. No.	Use Category of Space	Indoor Design Conditions	
		Dry Bulb Temperature (°C)	Relative Humidity (%)
1.	Restaurants, Cafeteria and Dining Hall	23 ~ 26	55 ~ 60
2.	Kitchens	28 ~ 31	--
3.	Office buildings	23 ~ 26	50 ~ 60
4.	Bank/Insurance/Commercial building	23 ~ 26	45 ~ 55
5.	Departmental stores	23 ~ 26	50 ~ 60
6.	Hotel guest rooms	23 ~ 26	50 ~ 60
7.	Ball room/meeting room	23 ~ 26	40 ~ 60
8.	Class rooms	23 ~ 26	50 ~ 60
9.	Auditoriums	23 ~ 26	50 ~ 60
10.	Recovery rooms	24 ~ 26	45 ~ 55
11.	Patient rooms	24 ~ 26	45 ~ 55
12.	Operation theatres	17 ~ 27	45 ~ 55
13.	Delivery room	20 ~ 23	45 ~ 55
14.	ICU/CCU	20 ~ 23	30 ~ 60
15.	New born Intensive care	22.5 ~ 25.5	30 ~ 60
16.	Treatment room	23 ~ 25	30 ~ 60
17.	Trauma room	17 ~ 27	45 ~ 55
18.	Endoscopy/Bronchoscopy	20 ~ 23	30 ~ 60
19.	X-ray (diagnostic & treatment)	25.5 ~ 27	40 ~ 50
20.	X-ray (surgery/critical area and catherization)	21 ~ 24	30 ~ 60
21.	Laboratory (diagnostics)	22.5 ~ 24.5	30 ~ 60
22.	Art Galleries/Museums	17 ~ 22	40 ~ 55
23	Libraries	20 ~ 22	45 ~ 55
24.	Radio studio/Television studio	23 ~ 26	45 ~ 55
25.	Telephone terminal rooms	22 ~ 26	40 ~ 50
26.	Airport terminal/ bus terminal	23 ~ 26	50 ~ 60

Note:

[a] The room design dry bulb temperature should be reduced when hot radiant panels are adjacent to the occupant and increased when cold panels are adjacent, to compensate for the increase or decrease in radiant heat exchange from the body. A hot or cold panel may be un-shaded glass or glass block windows (hot in summer, cold in winter) and thin partitions with hot or cold spaces adjacent. Hot tanks, furnaces, or machines are hot panels.

Source: Bangladesh National Building Code (BNBC, 2015)

Appendix 05: Filled up Questionnaire Form

Assessment of Thermal Condition of Naturally Ventilated Adult In-patient Wards During Warm Periods in Dhaka : Mugda 500 Bed General Hospital

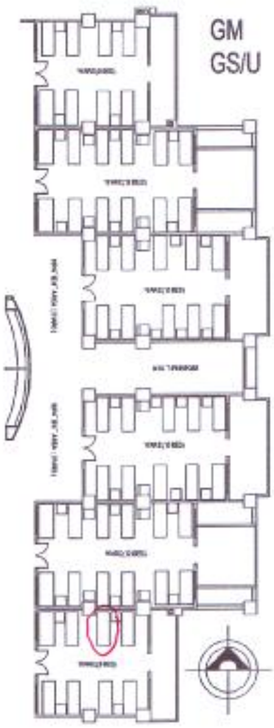
Date: 08/07

I) General Information:

1. Sample No : 407
2. Age: O 21-25 O 26-30 O 31-35 O 36-40
3. Gender: O Male O Female
4. Height: 5'-4" 5. Weight: 65
6. Skin Colour: Brown
7. Prior Experience of Hospital Stay: O Never O 1-2 O 3+ O ______
8. Length of Stay (Days): O 1-2 O 3-4 O 5-6 O 7+ O ______

II) Location/Position:

1. Which Floor of the building?: O 6th Floor O 8th Floor
2. Name of department O Surgical (Ortho/Eye/ENT) O Surgical (GS/Urology) O Medicine (Gen) O Medicine (Nephrology)
3. Location in the room/bay: O Near the window O Near the aisle O In between O Other
4. Are you near an exterior wall (within 15ft)? : O Yes O No
5. Are you near a window (within 15ft)? : O Yes O No



III) Control of space:

1. Which of the following do you personally adjust or control in your space?
   - O Window shades O Operable Windows
   - O Door to interior space O Door to exterior spaces
   - O Ceiling fan O Portable fans
   - O Natural lights O Artificial light
   - O None of this O Other ______

IV) Physical Condition:

1. How do you describe your physical strength?
   O Vigorous O Moderate O Frail O Very frail
2. Do you have any of the following Disease?
   OTB OBP O Fever X
   O Hyper/Hypo Thyroidism O Heat Stroke

V)

1. Do you experience change in indoor temperature during the day cycle?
   O Extreme Change O Huge Change O Slightly change
   O Very little change O No Change
2. When do you experience the highest thermal discomfort?
   O Morning (<11) O Mid-day (11-2) O Afternoon (2-5)
   O Evening (5<) O Always O Other

Time: 03:17 **T:** 31.1°c – 30.4°c **RH:** 75% **AV:** .9–.3

VI) Metabolic rate:

1. What is your current activity?

Reclining	Seating	Standing	Walking	Others

2. What did you eat/drink in the last 30 minutes? No

3. What was your last activity within the last 30 minutes?

Reclining	Seating	Standing	Walking	Others

VII) Clothing Insulation:

1. What you are wearing now? O Saree O Salwa Kameez O Long dress (Maxi) O Blouse O Under garments O Covered head (Orna) O T-shirt O Lungi O Trousers O Undershirt O Panjabi O Pajama
2. Are you covered with something? O Yes O No
3. If yes, what are you covered with? O Bed sheet O Katha O Other ____________

VIII) Temperature:

1. Thermal Sensation
How are you feeling at this current environment?

-3	-2	-1	0	1	2	3
Very cold	Cool	Slightly Cool	Perfect	Slightly Hot	Hot	Very Hot

2. Thermal Comfort:
How are you feeling at this current environment?

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3. Thermal Preference:
How do you like air temperature to be in your space?

-3	-2	-1	0	1	2	3
Extreme cold	Much Cooler	Slightly Cooler	No change	Slightly warmer	Much warmer	Extreme Hot

4. If there any source of heat in your space/ward? If yes, specify.____________

IX) Humidity:

1. How are you feeling (regarding humidity) inside the ward? (Sensation)

-3	-2	-1	0	1	2	3
Extremely Dry	Too Dry	Slightly Dry	Perfect	Slightly Humid	Very Humid	Absolute Humid

2. How are you feeling (regarding humidity) inside the ward? (Comfort)

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3. How do you like humidity to be in your space?

-3	-2	-1	0	1	2	3
Extremely Dry	Much Drier	Slightly Drier	No change	Slightly Humid	Much Humid	Extreme Humid

4. How is your skin, in term of wetness?

Very Dry	Dry	Just right	Drops of sweat	Wet

X) Air quality:

1. How are you feeling (regarding air circulation) inside the ward? (Sensation)

-3	-2	-1	0	1	2	3
Absolute Still	Too Still	Slightly Still	Just right	Slightly Breeze	Very Breeze	Highly Breeze

2. How are you feeling (regarding air circulation) inside the ward? (Comfort)

-3	-2	-1	0	1	2	3
Uncomfortable				Comfortable		

3. How do you like air quality to be in your space?

-1	0	1
Less Ventilation	No Change	More Ventilation

XI) Thermal Acceptability:

1. Is the thermal environment of your space acceptable at this moment?

-3	-2	-1	0	1	2	3
Not acceptable				Acceptable		

XII) Adaptation Measures:

1. When feeling 'hot' which type of measurement do you undertake?

Increase speed of ceiling fan	Changing levels of clothing/ covering	Change posture	Washing part of body/ Take Shower	Use Hand fan/ Table fan	Going outside room/ airy space/ Verandah	Others ______

2. Do you think the thermal comfort inside the wards have impact on your smooth recovery?

-1	0	1
Interferes	No Effect	Enhances

3. How do you think, your recovery will be faster by what type of change in your ward?

Increase number of ceiling fan	Increasing area of Window	Increasing air ventilation inside ward	Changing position/ orientation of ward	Reducing Humidity level	Reducing temperature level	Others ______

Appendix 06: Measured Environmental data during survey (Mean)

Day	Time	Air Temperature (^{0}C) (Mean)		Relative Humidity (%) (Mean)		Air Velocity (m/s) (Mean)	
		Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor
1	M	30	32.07	64.00	76.00	0.25	0.73
	N	35.7	31.93	58.00	75.00	0.25	0.82
2	M	30	32.28	64.00	75.67	0.95	0.64
	N	38.75	33.03	53.00	68.17	0.40	0.55
3	M	32	32.72	70.00	71.60	1.11	0.76
	N	35.3	33.03	61.00	67.60	0.95	0.78
4	M	32.5	30.52	75.00	78.33	0.50	0.55
	N	32.4	30.88	76.00	77.00	0.60	0.60
5	M	31.5	30.71	81.00	82.33	0.25	0.64
	N	31.8	31.06	83.00	77.83	0.47	0.83
6	M	31.4	30.34	81.00	81.40	0.40	0.61
	N	31.8	29.77	83.00	80.80	0.05	0.44
7	M	32.4	30.42	79.00	81.82	0.25	0.82
	N	33.2	30.86	72.00	78.73	0.40	0.60
8	M	30.4	30.77	83.00	83.00	0.20	0.58
	N	30.9	31.27	77.00	77.31	0.75	0.63
9	M	35.55	31.50	70.00	78.00	0.25	0.82
	N	34.45	31.55	72.00	78.83	0.05	0.80
10	M	31.7	30.13	81.00	84.33	0.25	1.00
	N	30.3	30.01	81.00	81.00	0.05	0.65
11	M	29.75	30.13	83.00	84.83	0.05	0.70
	N	30.8	29.59	81.00	83.33	0.05	0.88
12	M	30.75	30.57	76.00	83.17	0.60	0.66
	N	34	30.65	70.00	79.33	0.35	1.16
13	M	31.7	30.48	81.00	83.67	0.25	0.63
	N	30.3	30.08	81.00	80.83	0.05	0.48
14	M	31.95	31.37	74.00	76.64	0.55	0.50
	N	32.7	31.66	72.00	75.64	0.10	0.67
15	M	31.5	30.96	81.00	78.77	0.05	0.75
	N	33.6	31.38	73.00	75.85	0.05	0.94
16	M	31.9	31.07	80.00	82.00	0.32	0.62
	N	32.3	31.48	77.00	77.58	0.22	0.71
17	M	32	31.19	80.00	79.67	0.00	0.57
	N	32.1	31.50	74.00	76.17	0.70	0.50

***** M = Morning (8.30-10.30hrs)
N = Noon (02.00-04.00hrs)

Appendix 07: Master Data file for analysis (Summation of 400 responses)

Age

Age range	No of responses
20-25 years	132
26-30 years	110
31-35 years	72
36-40 years	86
Total	400

Sex

Male	212
Female	188
Total	400

VIII) Temperature:

1. Thermal Sensation
How are you feeling at this current environment?

Very cold	Cool	Slightly Cool	Perfect	Slightly Hot	Hot	Very Hot	
-3	-2	-1	0	+1	+2	+3	Total
0	0	8	168	190	34	0	400

2. Thermal Comfort:
How are you feeling at this current environment?

Uncomfortable				Comfortable			
-3	-2	-1	0	1	2	3	Total
0	22	198	0	180	0	0	400

3. Thermal Preference:
How do you like air temperature to be in your space?

Extreme cold	Much Cooler	Slightly Cooler	No change	Slightly warmer	Much warmer	Extreme Hot	
-3	-2	-1	0	+1	+2	+3	Total
0	28	269	97	6	0	0	400

IX) Humidity:

1. How are you feeling (regarding humidity) inside the ward? (Sensation)

Extremely Dry	Too Dry	Slightly Dry	Perfect	Slightly Humid	Very Humid	Absolute Humid	
-3	-2	-1	0	+1	+2	+3	Total
0	6	205	189	0	0	0	400

2. How are you feeling (regarding humidity) inside the ward? (Comfort)

Uncomfortable				Comfortable			
-3	-2	-1	0	1	2	3	Total
0	6	201	193	0	0	0	400

3. How do you like humidity to be in your space?

Extremely Dry	Much Drier	Slightly Drier	No change	Slightly Humid	Much Humid	Extreme Humid	
-3	-2	-1	0	+1	+2	+3	Total
0	6	202	192	0	0	0	400

X) Air quality:

1. How are you feeling (regarding air circulation) inside the ward? (Sensation)

Absolute Still	Too Still	Slightly Still	Just Right	Slightly Breezy	Very Breezy	Highly Breezy	
-3	-2	-1	0	+1	+2	+3	Total
0	0	130	205	61	4	0	400

2. How are you feeling (regarding air circulation) inside the ward? (Comfort)

Uncomfortable				Comfortable			
-3	-2	-1	0	1	2	3	Total
0	0	131	0	269	0	0	400

3. How do you like air quality to be in your space?

Less Ventilation	No Change	More Ventilation	
-1	0	+1	Total
0	107	293	400

XI) Thermal Acceptability:

1. Is the thermal environment of your space acceptable at this moment?

Not acceptable			Acceptable			
-3	-2	-1	1	2	3	Total
0	8	211	181	0	0	400

XII) Adaptation Measures:

1. When feeling ‘hot’ which type of measurement do you undertake?

Increase speed of ceiling fan	Changing levels of clothing/ covering	Change posture	Washing part of body/ Take Shower	Use Hand fan/ Table fan	Going outside room/ airy space/ Verandah	Others (Specify)	Total
32	72	48	24	52	164	8	400

2. Do you think the thermal comfort inside the wards have impact on your smooth recovery?

Interferes	No Effect	Enhances	
-1	0	1	Total
106	294	0	400

Appendix 08: Master Data file to correlate 'votings' (Responses of each question by each respondent)

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 1	1	1.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	1.00	0.00	1.00
	2	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00
	3	1.00	1.00	-1.00	1.00	0.00	0.00	0.00	2.00	1.00	0.00	1.00
	4	1.00	-1.00	-1.00	1.00	1.00	-1.00	1.00	2.00	-1.00	0.00	-1.00
	5	2.00	-1.00	-1.00	1.00	-2.00	-2.00	2.00	1.00	-1.00	1.00	-1.00
	6	2.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	7	1.00	-2.00	-1.00	1.00	-1.00	-1.00	2.00	-1.00	-1.00	1.00	-2.00
	8	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	9	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	-1.00	1.00	-1.00
	10	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	11	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	12	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
	13	1.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	1.00	0.00	1.00
	14	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00
	15	1.00	1.00	-1.00	1.00	0.00	0.00	0.00	2.00	1.00	0.00	1.00
	16	1.00	-1.00	-1.00	1.00	1.00	-1.00	1.00	2.00	-1.00	0.00	-1.00
	17	2.00	-1.00	-1.00	1.00	-2.00	-2.00	2.00	1.00	-1.00	1.00	-1.00
	18	2.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	19	1.00	-2.00	-1.00	1.00	-1.00	-1.00	2.00	-1.00	-1.00	1.00	-2.00
	20	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	21	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	-1.00	1.00	-1.00
	22	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	23	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	24	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
	25	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-2.00
	26	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-2.00
Day 2	27	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
	28	2.00	-1.00	-2.00	2.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	29	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00
	30	2.00	-1.00	-2.00	2.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	31	1.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	32	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	33	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	34	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	35	1.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	36	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	0.00	0.00	1.00	-1.00
	37	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	1.00
	38	2.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	39	1.00	-1.00	-1.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
	40	2.00	-1.00	-2.00	2.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 2	41	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00
	42	2.00	-1.00	-2.00	2.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	43	1.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	44	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	45	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	46	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	47	1.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	48	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	0.00	0.00	1.00	-1.00
	49	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	1.00
	50	2.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
Day 3	51	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	52	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	53	1.00	1.00	-1.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
	54	2.00	-2.00	-2.00	2.00	-2.00	-2.00	1.00	1.00	1.00	1.00	-1.00
	55	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	56	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	57	1.00	-1.00	-1.00	1.00	-1.00	-1.00	-1.00	-1.00	-1.00	1.00	-1.00
	58	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	59	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	60	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	61	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	62	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	63	1.00	1.00	-1.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00
	64	2.00	-2.00	-2.00	2.00	-2.00	-2.00	1.00	1.00	1.00	1.00	-1.00
	65	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	66	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	67	1.00	-1.00	-1.00	1.00	-1.00	-1.00	-1.00	-1.00	-1.00	1.00	-1.00
	68	2.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	69	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	70	2.00	-1.00	-2.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
Day 4	71	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	72	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	73	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	1.00
	74	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	75	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	1.00	1.00
	76	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	1.00	1.00
	77	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	78	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	79	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	80	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	81	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	82	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
	83	0.00	1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00
	84	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	85	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	1.00
	86	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	1.00	-1.00
	87	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
Day 4	88	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	89	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	90	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	91	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	92	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	93	0.00	1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00
	94	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	95	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	96	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	97	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	98	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
	99	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	1.00
	100	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	1.00
	101	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	102	1.00	-1.00	-1.00	1.00	-1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00
	103	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	104	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
Day 5	105	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	106	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	107	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	108	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
	109	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	110	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
	111	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	1.00
	112	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	1.00
	113	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	114	1.00	-1.00	-1.00	1.00	-1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00
	115	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	116	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	118	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	119	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	120	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
Day 6	121	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	122	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	123	-1.00	-1.00	1.00	1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00
	124	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	125	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 6	126	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	127	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	128	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	129	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	130	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	131	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	132	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	133	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	134	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	135	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	136	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	137	-1.00	-1.00	1.00	1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00
	138	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
Day 7	139	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	140	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	141	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	142	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	143	-1.00	-1.00	1.00	1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00
	144	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	145	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	146	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	147	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	148	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	149	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	150	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	151	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	152	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	153	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	154	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	155	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	156	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	157	-1.00	-1.00	1.00	1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00
	158	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	159	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	160	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
Day 8	161	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	162	1.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	163	0.00	1.00	-1.00	0.00	1.00	-1.00	0.00	0.00	1.00	1.00	1.00
	164	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	165	0.00	1.00	-1.00	0.00	1.00	-1.00	0.00	0.00	1.00	1.00	1.00
	166	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	167	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 8	168	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	169	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	170	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	171	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	172	1.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	173	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	174	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	175	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	176	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	177	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	178	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	179	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	180	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	181	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	182	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	183	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	184	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
Day 9	185	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	186	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	187	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	188	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	189	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	190	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	191	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	192	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	193	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	194	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	195	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	196	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	197	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	198	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	199	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	200	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	201	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	202	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	203	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	204	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	205	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	206	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	207	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
	208	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
	209	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	210	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	211	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	212	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	213	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	214	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	215	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	216	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	217	-1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	218	-1.00	-1.00	1.00	0.00	1.00	0.00	0.00	1.00	-1.00	0.00	1.00
	219	-1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
Day 10	220	-1.00	-1.00	1.00	0.00	1.00	0.00	0.00	1.00	-1.00	0.00	1.00
	221	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	222	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	223	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	224	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	225	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	226	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	227	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	228	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	229	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	230	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	231	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	232	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	233	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	234	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	235	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	236	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	237	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	238	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	239	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	240	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
Day 11	241	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	242	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	243	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	244	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	245	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	246	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	247	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	248	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	249	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	250	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 11	251	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	252	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	253	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	254	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	255	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	256	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
Day 12	257	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	258	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	1.00
	259	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	260	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	261	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	262	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	263	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	264	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	1.00
	265	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	266	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	267	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	268	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	269	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	270	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	271	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	272	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	273	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	274	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	275	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	276	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	277	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	278	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
	279	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	280	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
Day 13	281	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	282	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	283	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	284	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	285	1.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-2.00
	286	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	287	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	288	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	289	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	290	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	291	1.00	-2.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-2.00
	292	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 13	293	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	294	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	295	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	296	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	297	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	298	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	299	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	300	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	301	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	302	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	303	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	304	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
Day 14	305	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	306	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	307	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	308	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	309	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	310	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	311	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	312	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	313	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	314	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	315	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	316	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	317	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	318	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	319	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	320	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	321	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	322	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	323	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	324	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	325	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	326	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
Day 15	327	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	328	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	-1.00
	329	0.00	1.00	0.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	330	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	331	0.00	1.00	0.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	332	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	333	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	334	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	-1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
	335	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	1.00
	336	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	337	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	338	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	339	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	340	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	341	0.00	1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	1.00
	342	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
Day 15	343	1.00	-1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00	1.00	-1.00
	344	1.00	-1.00	-1.00	0.00	1.00	0.00	1.00	0.00	1.00	1.00	-1.00
	345	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	346	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	347	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	348	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	349	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	350	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	351	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	352	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	353	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	354	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	355	0.00	1.00	-1.00	0.00	1.00	-1.00	0.00	0.00	1.00	1.00	1.00
	356	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	357	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	358	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	359	0.00	1.00	0.00	1.00	-1.00	-1.00	1.00	-1.00	1.00	1.00	-1.00
	360	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	361	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	362	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	363	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
Day 16	364	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	365	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00
	366	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	367	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	368	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	-1.00
	369	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	370	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	371	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	372	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
	373	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	374	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	375	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	376	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00

	No	Responses of										
		Q-VII(1)	Q-VIII (2)	Q-VIII (3)	Q-IX (1)	Q-IX (2)	Q-IX (3)	Q-IX (4)	Q-X (1)	Q-X (2)	Q-X (3)	Q-XI
Day 17	377	0.00	1.00	0.00	1.00	-1.00	-1.00	0.00	0.00	1.00	0.00	1.00
	378	0.00	1.00	-1.00	1.00	-1.00	-1.00	0.00	0.00	1.00	1.00	-1.00
	379	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	380	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	381	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	382	1.00	-1.00	-1.00	1.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-2.00
	383	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	384	1.00	-1.00	-1.00	1.00	-1.00	-1.00	0.00	-1.00	-1.00	1.00	-1.00
	385	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	386	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	387	0.00	1.00	-1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00
	388	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	389	0.00	1.00	0.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	1.00
	390	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	391	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	1.00	-1.00
	392	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	0.00	1.00	0.00	-1.00
	393	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	394	1.00	-1.00	-1.00	1.00	-2.00	-2.00	1.00	-1.00	-1.00	1.00	-2.00
	395	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00
	396	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00	-1.00	1.00	-1.00
	397	1.00	-1.00	-1.00	0.00	1.00	0.00	0.00	-1.00	-1.00	1.00	-1.00
	398	1.00	-1.00	-1.00	1.00	-1.00	-1.00	0.00	-1.00	-1.00	1.00	-1.00
	399	0.00	1.00	0.00	1.00	-1.00	-1.00	0.00	0.00	1.00	0.00	1.00
	400	0.00	1.00	-1.00	1.00	-1.00	-1.00	0.00	0.00	1.00	1.00	-1.00