A case study on thermal comfort in maternity hospital in Beijing

Boyu DU

Student ID: 20026009

Department of Architecture and Built Environment

University of Nottingham, Ningbo, China

Submitted August 2018, in partial fulfilment of the conditions of the award of the degree MRes. in Sustainable Energy and Building Technology

I hereby declare that this dissertation is all my own work, except as indicated in the text:

Signature: __________

Date: ____/____/____

Abstract

Thermal comfort is a vital evaluation of indoor thermal comfort, which is widely applied in economic building, office building and school building etc. Compared to previous investigations in general hospital, only a few studies focused on maternity hospital. In this research, thermal comfort in a maternity hospital was investigated whether there was a comfort environment for pregnant women's delivery, visitors' accompany and staff's working. In order to ensure the measurements are scientific and suitable, both foreign and domestic researches were referred in terms of thermal comfort in hospital. Both objective and subjective measurements were conducted in a maternity hospital in transition season ranging from March to April in Beijing. The objective measurements such as air temperature, relative humidity, air velocity and carbon dioxide were recorded by equipment placed in one ward, one doctor's office and one nurse station, respectively. The subjective measurements included personal clothing insulation, activity levels, thermal sensation, thermal expectation, humidity sensation and other sensibility related to environments were collected by 168 effective questionnaires. The linear regressions were applied to compare the relationship between the thermal sensation and environmental parameters and personal factors. The result showed that a) Indoor temperature and humidity basically met the requirements of domestic standard, which were 24.52-26.91℃ and 24.29-28.84℃ in March and in April, respectively; the relative humidity was ranged from 25.44-42.40% and 32.66-64.00% in March and in April, respectively. b) There was no difference between subjective and objective thermal sensation values, $p=0.101$, however, the average value of objective was higher 1.57 than that of subjective, which indicated that people felt warmer than

PMV predicted sensation. c) Individual’s actual thermal sensation was various in different months which individual would feel warmer in the basically same indoor temperature in ventilation season than heating season.

Acknowledge

I would like to thank Dr. Liang Xia for supporting me to finish this research and for guiding every time before I started field work.

I would like to thank the hospital where I conducted my research for providing me a chance to access patients, visitors and staff.

I would like to thank Dr. Lawrence Lau, Dr. Lily Cai and other staff working for MRes program for providing me useful academic training.

I would like to thank my family, my friends, Jiapei Li and Jianrui Wang for always supporting me. I love you all.

List of Figures

List of Tables

Glossary of Symbols

M Metabolic rate, in Watts per square meter of the body surface area, W/m^2

W Effective mechanical power, equal to zero for most activities, W/m^2

C Heat loss by convection, W/m^2

R Heat loss by radiation, W/m^2

E Respiratory heat loss by evaporation and convection, W/m^2

S Heat storage rate, W/m^2

I_{cl} Thermal resistance of clothing, m^2*K/W

f_{cl} Ratio of surface area of the body with clothes to the surface area of the body without clothes

t_a Air temperature, ℃

t_r Mean radiant temperature, ℃

V_{ar} Relative air velocity, m/s

P_a Water vapor partial pressure, in Pascal

h_c Convective heat transfer coefficient, W/(m^2*K)

t_{cl} Clothing surface temperature, ℃

t_op Operative temperature, ℃

h_r Radiative heat transfer coefficient, W/（m^2·℃）

RH Relative humidity, RH%

CO_2 Carbon dioxide, ppm

Abbreviations

PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfaction
PMV_e	Expected Predicted Mean Vote
PPD	Predicted Percentage dissatisfaction
ASHRAE	The American Society of Heating, Refrigerating and Air-conditioning Engineers
ISO	International Organization for Standardization
e	Expected factor
TSV	Thermal Sensation Vote
TCV	Thermal comfort Vote
ET	Effective Temperature
ET*	New Effective Temperature
SET	Standard Effective Temperature

List of Content

Chapter 1 Introduction

Up to 2016, the population in China has been 1,382,710,000, which will keep increase with the development of economy and the promulgation of the Two Child Policy [1]. According to the data published by National Bureau of Statistics of the People's Republic of China [1], compared with 16,318 hospitals, 21,760,000 beds, 20,760,000 doctors and 4586.6 trillion RMB for health care in 2000, China has already had 29,140 hospitals, 56,890,000 beds, 31,910,000 doctors and spends 46344.9 trillion for health care so far. It shows that the scales of hospitals are expanded with the number of hospitals going up. At the same time, people show a higher demand for hospital environments. Therefore, it is necessary to optimize the hospital environment for establishing the requirements of patients, visitors and staff.

Hospital is an important place for the patients to recover from injury, surgery and disease. Research shows that creating a comfortable environment for patients will help them to manage their emotions so that they can better recover [2]. Hospital has strict functional zonings for different subset of patients, and the requirements of different departments are varied as well. Meanwhile, variety of pathogens coexist are existing in hospital, which have effect on susceptible individuals occupying in hospital. Therefore, the environmental system in hospital is different from other building based on above characteristics. The environments will help to medical treatment, enhance working efficiencies and deliver medical care as well.

Since the eighteenth Century, with the rise of women's status, promoting the health of women and children has gradually been concerned by the society. As a kind of hospital, the maternity hospital is established for women, children and pregnant women, which played an important role in domestic medical and health field. However, according to the domestic research, the number of bed in maternity hospitals had a significant positive correlation with the maternal mortality, and had a significant negative impact on survival rate [3].

As habitants in maternity hospital, pregnant women, visitors and staff formulate various requirements to the environments. Patients who are admitted to the in-patient department are usually physically weak. The pregnant women are different from ordinary patient because they are in healthy status. They are still vulnerable due to the decrease of immunity. It is about three days for pregnant women staying in hospital from delivery to the observation of postpartum. Hospitalized pregnant women want to stay in single room, which can guarantee the privacy to reduce their concern, create a quiet environment for rest and facilitate the family a better visit. Therefore, pregnant women need more humane ward where they can adjust the indoor temperature, lighting and other equipment according to their psychological and physiological needs [4]. It is a delightful and hard work for visitors who need to take care of the newborns and the pregnant women who are in labor or at the end of the delivery. Thus, hospital should pay attention to their consideration of rest and moods in addition. As long-time habitants, staff work from 8 am to 5 pm every day and some of them work at night, which make them more familiar with hospital. Their metabolic rate of activity levels and clothing insulation would differ from pregnant women and visitors, which depend on their work load. As it proved before, thermal comfort can influence work efficiency [5] and work time [6]. From the perspective of engineering, creating a comfortable environment for habitants in maternity is also a crucial part to serve the maternal and improve the staff's working efficiency and their health. Therefore, it is necessary to pay attention to the development of indoor climate in hospital.

In this paper, the major objective is to analyze objective thermal sensation and subjective thermal sensation to evaluate the indoor climate in maternity hospital. This evaluation is based on PMV, which combined the environmental factors and personal factors together to quantify the relationship between the indoor climate and the people. PMV is an objective value. This research also collected the subjective thermal sensation vote by using questionnaire. By comparing the subjective thermal sensation and the objective thermal sensation, this research finds that the occupants preferred slightly cool indoor climate and they can tolerate the slightly dry environment.

For the sake of conducting the conclusion what mentioned above, the detailed objectives are:

- To investigate the thermal and humidity conditions in maternity hospital.
- To describe the thermal comfort and thermal requirements of habitants in maternity hospital.
- To validate the PMV model by comparing the PMV values and TSV

values in maternity hospital.

- To figure out the differences in thermal comfort between different months, identities, room types and different number of surrounding people.
- To provide suggestions for optimizing the environment in maternity hospital in the future.
- To provide suggestions for the formulation of relevant standards of indoor thermal environment in maternal hospitals in China.

Chapter 2 Literature review

The requirements of thermal comfort in hospital are high and multiple. Firstly, the functions of different departments is complex account for different body check and various disease [7]. For example, rheumatic patients, they need a rehabilitation environment with high temperature and low humidity. Suitable temperature and humidity environment can assist treatment, improve treatment effect and improve individual metabolism level [8]. Moreover, the hospital should be operated with good ventilation system due that: 1.the pollution source of hospital is complex; 2.the closed space environment is beneficial to breed bacteria; 3.the number of mobile people is relatively large. A ventilation system of the hospital providing suitable temperature and humidity environment [8] can guarantee the air quality and prevent the pollution spread.

With different research purposes, researchers have focused on thermal comfort in various departments of hospital. In addition, identity is another research topic, because the time length of staff, patients, visitors varies, which have effects on thermal comfort.

Studies concerning hospital thermal comfort conducted by foreign researchers were earlier than domestic scholars. Many results have been obtained by these foreign scholars. Their researches can be divided into two parts including the effect of factors on thermal comfort in hospital and the verification of whether PMV can predict individual's thermal comfort in hospital. However, there is a lack of researches on thermal comfort for pregnant women, maternity staff and visitors. Meanwhile, only a few domestic researches focus on the relationship between patients and the hospital environments. These researches are mainly concentrated in the Chongqing area. Scholars work begin with investigating the hospital environment parameters and gradually turn to indoor climate thermal comfort in hospital.

In this chapter, literature review will focus on thermal comfort in hospital as well as thermal comfort theory. Moreover, some gaps of these researches will be shown in the end of this chapter.

2.1 Overseas researches

In March 2009, Jan Verheyen et al. [9] finished a field work in Belgium which involved 99 patients living in six in-patient departments of one hospital. PMV was not well applied for neurology department due to the injuries of brain and nervous system. The injuries influenced people's thermophysiology and regulation. This research also noted that patients preferred warmer environment. This research was the only one article which included pregnant women. By using the self-described health questionnaire, it was proved that pregnant women were healthier than other patients; PMV was a good predictor for pregnant women's subjective thermal comfort.

There was a remarked correlation between patients' physical strength and thermal requirements, which was proved by Hwang et al. [10]. This research was conducted in wards of a university hospital with 927 participants in Taiwan. It noted that patients required warmer environments than healthy individuals by using probit analysis. The results of Chi-square tests also revealed that the correlations between the time length of staying in hospital, gender, age and thermal sensation was weak.

Pourshaghaghy and Omidvari [11] used PMV model directly to check thermal comfort of a hospital with 40 years history. This research was conducted in winter and summer including morning, afternoon and night. The measurement areas were located in different section. This research involved 84 patients, 49 staff and 32 visitors. It determined three findings. Firstly, the separate heating system would lead higher dissatisfaction. Secondly, the poor thermal situation would occur in winter morning. Thirdly, the gender difference in thermal comfort existed in both winter and summer. As Wang [12] mentioned in previous study that the neutral operative temperature of males was 1 ℃ lower than females.

Skoog [13] conducted a research in Sweden with staff and patients. The results revealed that it was necessary to divide the occupants in hospital into different groups. Adaption also played an important role on thermal comfort, for how staff perceive the climate was influenced by how they felt throughout the year.

In Thailand, Sattayakorn et al. [14] conducted a field work in out-patient department of one public hospital(H1) and one private hospital (H2). It determined that PMV mismatched with actual thermal sensation. Compared to patients, both staff and visitors expected cooler environment. As short time habitants, patients just focused on illness and had lower expectation to the environment, but they expected a warmer environment. The longer the patients stayed in hospital, the higher requirements they would reveal. As long-time habitants for hospital, medical staff were in good physical conditions and worked for more than 10 hours a day with high metabolic rate. So their demands for the environment was more stable than other group of people.

Del Ferraro et al. [15] conducted a research in an Italian hospital in winter with 58 participants. 49 of 58 questionnaires could be used to calculated PMV; however, PMV was not a good predictor to evaluate actual thermal comfort in this study. They also noted that gender differences, age differences as well as identity differences were also needed to be considered.

As a part of environments, humidity issue could not be ignored due that the low-humidity environments was contributed to health problems as well [16]. After installed the humidifiers in sickroom in a field study in Japan, the relative humidity of sickrooms increased from 32.9% to 43.9%, which demonstrates that number of the discomfort staff members decreased during winter [17]. This proved the importance of relative humidity.

2.2 Domestic researches

In order to figure out whether humidity environment would influence human health in hospital where operated by air-conditioning system in summer, Zhang et al. [8] applied grey system theory and cloud model. The results showed that the best relative humidity range for human health was 65-70% and the best air temperature range was 25-27°C.

Qi et al. [18] carried out a field experiment in in-patient department in Chongqing, which conducted in winter and summer. The purpose of their research was to evaluate the indoor humidity comfort requirements. It determined that the physical status would influence individuals' sense of humidity. Patients required a higher humidity environment. Due to the features of Chongqing which was hot and humidity, Chongqing people formed an ability to adapt higher humidity.

Yu et al. [19] applied Ireton-Jones equation [20] to calculate the metabolic rate of activity levels of patients who lying on beds. In this study, they found that the value of PMV whose metabolic rate of activity level calculated by Ireton-Jones equation was much closer to the actual value. Thus, it would be a scientific way to apply Ireton-Jones equation for calculating PMV.

In addition, studies on thermal comfort and humidity comfort for different identities in hospital were conducted by Gong et al. [21, 22]. These researches were conducted in winter and summer with patients occupying in in-patient department, visitors and staff occupying in out-patient department. They concluded that people in different areas required various thermal environment. However, their researches were similar to Yu's [19], which both ignored the heat exchange between people and the environment.

Another work conducted by Feng [23] in both summer and winter in Chongqing. This research involved physical status questionnaire delivery and insulation of bedding system, which made research more scientific. This research just focused on patients. It reveals that the neutral temperature for patients were 21.3 ℃ and 24.8 ℃ in winter and summer respectively, the expected temperature was 22.3℃ and 25.1 ℃.

2.3 Theory of Thermal comfort

Scholars from all over the world have made a great deal of contributions to the development of thermal comfort. As the representative of thermal comfort study, Fanger [24] have laid the foundation for thermal comfort.

In 1970, Fanger [25] proposed the concept of Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfaction (PPD)， the purpose of which was to connect the factors which maintain the body temperature in balance together. The PMV model is associated with the environmental factors (relative humidity, air temperature, clothing heat resistance, radiant temperature) and individual factors (clothing thermal resistance, human activity level), which was based on extensive experimental results in laboratory. Subsequently, the model has been applied everywhere in the world [5, 26-28]. ISO 7730 [29] and ASHRAE 55 [30] include the thermal comfort model of Fanger. The standards are designed for the requirements of engineers in HVAC and related fields.

Another theory related to thermal comfort is thermal adaption, which was put forward by de Dear and Brager in 1988 [31]. This theory was based on Humphreys and Nicol's [32] finding. The thermal adaptation can be categorized in physiological adaptation (based on exposure to the environment), psychological adaption (based on personal willing to change the environment) and behavior adjustment (window opening, opening, opening fans, etc.).

2.3.1 Human thermal comfort

The thermal comfort requires that: a) individual should be in the state of thermal balance b) average temperature of skin should be adapted to the thermal comfort level c) individual should have appropriate perspiration rate to satisfy comfort.

The thermal balance equation is expressed as Equation (2.1):

$$\mathrm{M} - \mathrm{W} - \mathrm{C} - \mathrm{R} - \mathrm{E} - \mathrm{S} = 0 \qquad (2.1)$$

Where:

M: is metabolic rate, in Watts per square meter of the body surface area, W/m^2.

W: is effective mechanical power, in Watts per square meter, equal to zero for most activities, W/ m^2.

C: is heat loss by convection, in Watts per square meter, equal to zero for most activities, W/ m^2.

R: is heat loss by radiation, in Watts per square meter, equal to zero for most activities, W/ m^2.

E: is respiratory heat loss by evaporation and convection, in Watts per square meter of the body surface area, W/ m^2.

S: is heat storage rate, in Watts per square meter of the body surface area, W/ m^2.

The heat exchange between human body and external environment is affected by clothing. In addition, the heat transfer is also influenced by the ambient temperature, because convection heat transfer is mainly determined by the ambient temperature. Convection heat exchange coefficient is also influenced by air velocity. Latent heat exchange only dissipates heat from the pathway of respiration and skin evaporation. At a certain temperature, the relative humidity affects water evaporation of skin, which affects the emission of heat further. Therefore, when an individual is exposed to a high temperature and a high humidity environment, he will have higher heat sensation. On the contrary, when the ambient temperature is low and the humidity is a little wetter, the clothes will be more moist, which will enhance the heat transfer.

2.3.2 PMV and PPD model

The definition of thermal sensation is described as how the individuals perceive the environment. Sometimes individual will feel cold, sometimes he will feel hot or sometimes he will feel neutral. However, the thermal sensation cannot be measured by equipment. Thus, questionnaire is used to ask people to describe their actual thermal sensation according to standardized scale. At present, ASHRAE7-point scale showing on Table 2.1 [30] is the most widely used subjective questionnaire to describe the sensation of hot or cold by rating their thermal sensation. Fanger proposed [25] Predicted Mean Vote (PMV) to quantify the relationship between personal factors and environmental factors together. The principle to calculate PMV is based on Equation 2.1.

Table 2.1 ASHRAE 7-point scale.

Sensation vote	Description
-3	Cold
-2	Cool
-1	Slightly cool
0	Neutral
+1	Slightly warm
+2	Warm
+3	Hot

The definition of neutral is that individual feel neither cold nor hot. When people feel neutral, it demonstrates that heat dissipating and heat producing can reach a balance. Less energy is used to regulate body temperature, thus body temperature remains constant. However, the definition of neutral sensation and thermal comfort is still controversial. De Dear, Brager [33] and Fanger [25] claimed that when people felt neutral, they had been in comfortable environment. Some scholars may disagree with them. Zhao [34] summarized the previous findings conducted by Gagger [35], Hensel [36], Chatonnet and Cabanac [37]. He concluded that thermal comfort was not durable, but a dynamic process accompanied with the changes of environments. This study agrees with the previous one due that participants stayed in a stable environment.

Thermal comfort is distinguished from thermal sensation, therefore, TCV (Thermal Comfort Vote) is applied to evaluate the level of thermal comfort. Table 2.2 shows 5-point scale on thermal comfort.

Table 2.2 Thermal comfort vote.

Sensation scale	Description
0	Comfort
1	Slightly uncomfortable
2	Uncomfortable
3	Very uncomfortable
4	Cannot tolerate

When people are habituating indoor, their thermal sensation are influenced by environmental parameters and personal factors. Air temperature, radiant temperature, relative humidity and air velocity are included in environmental factors; clothing insulation and metabolic rate are included in personal factors. Researchers propose many index to describe how environment influence personal thermal comfort, which are based on a great deal of both laboratory experiments and field experiments. PMV model is the most widely used method to observe thermal sensation. The results of PMV coincide with 7-point scale. In order to calculate the percentage of dissatisfaction, Predicted Percentage of

Dissatisfaction (PPD) was proposed by Fanger at the same time. The theoretical basis of PMV model is that under stable thermal environment, there is a positive relation between the heat load and the deviation degree of thermal comfort. The greater the positive thermal load is, the warmer the thermal sensation is; The greater the negative value is, the colder the thermal sensation will be.

2.3.3 Limitation of PMV model

More and more field investigations show that there is an apparent deviation when comparing the value of actual thermal comfort and PMV under non-air-conditioned environment. Fanger [38] argued that people has an expectation of the environment in the non-air-conditioned environment. Therefore, Fanger introduced an expected factor "e" within 0.5-1 to modify the currently PMV in warm climate. The specific values are determined by the annual duration of the hot weather and the ratio of natural ventilation to the number of air-conditioned buildings. In the areas with longer thermal weather and more natural ventilation buildings, the corresponding expectation factors will be relatively small.

$$\mathrm{PMV_e} = \mathrm{e} \times \mathrm{PMV} \tag{2.2}$$

Where:

$\mathrm{PMV_e}$: expected PMV

e: expected factor.

Before this modification, de Dear and Brage [31] had already proposed an adaption model. It emphasized that the individual was an adaptor for the environment rather than a passive recipient. Human adaptation could be divided into physiological, behavioral and psychological adaptation. There are plenty of experiments proving thermal adaption assumption in domestic buildings. Cao et al. [39] demonstrated that people who lived in a hot climate for a long time are resistant to high temperature, which were physiological adaption and regulation. Another research also conducted by Cao et al. [40] indicated that if habitants could regulate the temperature according their need, they could accept higher temperature, which was behavior adaption.

2.4 Previous methodology

Referring to the previous study on thermal comfort in office building, residential building and school building, research methods of thermal comfort include laboratory experiment, field experiment and computer simulation by delivering psychological questionnaire, collecting physiology data and measuring environment parameters.

- Laboratory experiments are based on constructing microclimate chambers to conduct controlled experiments. The early researches of Fanger were based on experimental experiments. In order to investigate whether there was a difference in preferred temperature for ordinary people and the people who exposed to the cold environment for a long time, the two groups of participants were asked to sit in the same lab with the same clothes and asked to adjust the temperature according to their expectation [41]. Another research conducted by Fanger [42], which involved 8 males and 8 females, was to find the effect of color and noise on thermal comfort. They were asked to sit in the same laboratory with clothes of 0.6 clo. They were stimulated by red light, blue light, 40dB (A) and 85dB (A) successively. These are two classic laboratory experiments mentioned above, the principal of laboratory experiments is shown as follows. In the artificial climate laboratory, the researchers can control the indoor environment parameters by air conditioning system or according their research topic. During the experiment, they can ask the participants to dress in the same clothes, do the same activity. Participants are required to evaluate their thermal comfort under strictly controlled environmental conditions. In the artificial climate environment, it is more conducive to three types of research: 1) to investigate the effect of a variable or a combination of variables on thermal comfort 2) To investigate whether people can tolerate extreme environments, which are not available in real buildings 3) To observe the change of physiological indexes and to investigate how human body reflect thermal comfort. By measuring the skin temperature [43] , heart rate variability [44], metabolic and brain waves [45, 46], myoelectricity [47] and perspiration rate [48], researchers can observe the relationship between physiological response and thermal comfort sensation.

- The definition of field work in terms of thermal comfort is to deliver questionnaire and to measure environmental parameters. Compare to laboratory experiments, the work load of field work is much larger. Luckily, field work ensures the authenticity of the research environment and reflects the interaction between people and the environment. So far, the evaluation methods of subjective thermal comfort are very limited, which is mainly obtained by questionnaire survey [10, 14, 23]. Bedford [49] and ASHRAE 7-point scale are widely used. It required the participants to rate their thermal sensation based on actual feeling. Researchers will evaluate the collected values. As mentioned above, questionnaire delivery is one of psychological methods to investigate the thermal comfort. Behavioral test [50] is another way to investigate it.

- With the development of computer science, it is more common to simulate thermal comfort by means of computer simulation software. In order to find the best environmental situations for both thermal comfort and eliminating pollution, Ho [51] applied computational fluids dynamics (CFD) and linear regression in operate rooms designed by heating, ventilating and air-conditioning system (HVAC). They model an operate room in three-dimensional including patients' box, operate box, surgical light, supply grille and exhaust grille in order to conduct numerical value simulation including air speed, temperature, water vapor and pollution boundary conditions. How they got PMV is also based on Fanger's model. The results present that: Supply grillers should be put in the center of a room to realize the best performance; In cooling mode, the cooler the better thermal comfort is and the lowest temperature range is 22.3 to 22.4℃; There is no difference between entire space and breathing zone when make a simple assessment for thermal comfort by using air speed and mean relative humidity.

2.5 Shortage of previous research

For the length of time for occupants who stay in in-patient department is longer than the occupants who just go to the out-patient department. It is necessary to create a comfortable environment for them no matter they are under treatment or have a rest of the whole day. The indoor climate should be observed at first. However, the indoor climate data for thermal comfort just recorded as delivering questionnaire. The hourly and daily changes should be measured as an evidence for design and operating in the future.

To verify whether PMV is a good predictor to evaluate thermal comfort in hospital is still controversial. Domestic researches on thermal comfort of hospitals were concentrated in Chongqing area. It is still insufficient in areas with large population, such as Beijing, Shanghai, Guangzhou et al.. Meanwhile, previous studies have focused on thermal sensation to evaluate the indoor climate. However, the effect of environment on other sensibilities are ignored, for example, the sensibility of humidity. Therefore, researchers should expand their research area when they study on people's environmental comfort in hospital. This will help to find what parameters can help to predict people's satisfaction to the indoor climate.

According to Fanger's advice [52], he claimed the importance of individual control behavior to fulfill the personalize requirements. It is obvious that in domestic hospital, people have to share one wards with other patients due to limited beds. Considering their needs, it will help to create an user-friendly environments as well as help to heal. Therefore, personalize control should be included in the future study. Before personalize survey, it is necessary to have an overall understanding of hospital including the environments and personal requirements.

There is a lack of thermal comfort researches in China and Chinese hospitals in addition. Domestic standard [53, 54] just put forward the requirements of temperature, humidity and air velocity for some departments of the hospital, which are not sufficient to support the overall environmental design of hospital. For example, only a brief introduction in terms of maternity ward environmental standard is provided by GB 51039-2014[53], which newborn room should be operated in the range of 22-26 ℃. However, the air temperature, relative humidity and air velocity for other room, such as delivery room, preparation room and shower room are not involved. It is not possible to design and operate hospital buildings only by reference to the parameters and the experience of other buildings. Therefore, this research aims to provide reference for standardizing Chinese hospital.

In order fill the neglected research topic mentioned above, the detailed research purposes are showed as follows:

- What is the current hospital environment and whether this hospital satisfies the requirements of individuals;
- What is the best environmental conditions for hospitals in Beijing area;
- Whether PMV is a good predictor to evaluate indoor climate.
- It is confirmed that indoor environmental conditions are related to personal behaviors (such as window opening and automatic temperature regulation). It hopes that this on-site investigation can provide suggestions for future hospital design.

Chapter 3 Methodology

This research was carried out in in-patient department of a state-owed maternity hospital in the city of Beijing, China. The purposes of this research are to determine personal needs for thermal comfort in hospital and to validate the applicable of Predicted Mean Vote (PMV) and Predicted Percent of Dissatisfied (PPD) in hospital. Subjective data (clothing insulation, metabolic rate of activity level) and objective data (air temperature, relative temperature, air speed and globe temperature) were collected in March and April in 2018. In data processing section, two-sample t-tests and ANOVA analysis were conducted for thermal sensation to determine whether the difference between the average of PMV and TSV was significant on a 5% level. Binomial tests were used to calculate to acceptable operative temperature range, preferred temperature and acceptable temperature in hospital in terms of comfortable environments for occupants in hospital. In addition, the subjective PPD was observed by occupant votes.

Questionnaire delivery was approved by UNNC Ethics Subcommittee after supervisor evaluated risks.

In this chapter, the basic information on target hospital, data collection and data processing will be presented.

3.1 Basic information

Figure 3.1 Experiment site.

This field work was conducted in in-patient department of maternity hospital in Beijing. This hospital was founded in 1982. There are 45 sets of double rooms, 28 sets of triple rooms including 164 beds as well as temporarily extra bed up to 30 in the hospital. The size of each room is the same, which is 3.3 m * 5.8 m. The number of beds in double room and triple room is two and three respectively. In addition, there is an independent washing room in double room, however, there is no independent washing room in triple room. Sometimes double room will be used as single room.

Normally, it is about three days for pregnant woman to be hospitalized during the parturition period. Due to the limitation of the number of beds, pregnant women are mixed with whom she has already delivered. Meanwhile, new-born infants live with their mother as well.

This hospital is operated with central heating system every year. The heating season lasts from November 1 to March 30 of next year. In summer, the separate air conditioning system is applied in every room. People can adjust the indoor temperature according to personal demand. The new wind system is not applied in this hospital, and new fresh air is brought inside as people move and window opened.

3.2 Measurements

The field survey was conducted twice, from the morning of March 6 to the evening of March 12, 2018, and from the noon of April 22 to the morning of May 2, 2018.

During the data collection period, the opening and closing of indoor doors and windows and the number of surrounding people were in a natural state, and participants could open and close according to their own needs. Therefore, in the questionnaire part, participants were asked to fill in the indoor window opening state and the number of surrounding people. This result will be elaborated in Chapter 4.

3.2.1 Objective measurements

3.2.1.1 Measurement parameters

The continuous data including air temperature, relative humidity, air speed and carbon dioxide. They were collected from a ward, a doctors' office and a nurse station.

The specific test content was summarized as follows on Table 3.1:

Table 3.1 Objective information on environment.

Test position	Test object	Unit
Doctors' office	Air Temperature	℃
	Relative Humidity	RH%
	CO_2	ppm
Double room ward	Air Temperature	℃
	Relative Humidity	%
	Air velocity	m/s
	CO_2	ppm
Nurse station	Air Temperature	℃
	Relative Humidity	%

3.2.1.2 Measurement equipment

According to ISO 7730 [29], air temperature, relative humidity, carbon dioxide, air velocity and mean radiate temperature was conducted to calculate PMV. However, it was not appropriate to put the globe thermometer in ward in the whole period due to the limitation of room size inside. The definition of mean radiant temperature shows that it is equal to the mean values of surrounding temperature [55]. After observing several data by using globe thermometer before measuring, which radiant temperature was similar to air temperature, therefore, air temperature would be used to represent radiant temperature [56] when calculating PMV and PPD in this research.

Thermometer (Testo 175 H1), Wind speed & wind temperature data logger (WFWZY-1) and Environmental data logger (HCZY-1) showed in Figure 3.2 were applied during this research. The detailed information of these equipment is shown on Table 3.2.

Thermometer (Testo 175 H1)

Wind speed & wind temperature data logger (WFWZY-1)

Environmental data logger (HCZY-1)

Figure 3.2 Pictures of sensors.

Table 3.2 Basic information on equipment.

	Parameter	Range	Accuracy	number	Location	Applied time
Thermometer	Temperature	-20 - 55 °C	±0.4 °C	1	Nurse station; Outdoor	April
	Humidity	0 - 100%	±2%			
Wind speed & wind temperature data logger	ventilation	0.05 - 30 m/s	5% ± 0.05m/s	1	Ward	March; April
Environmental data logger	temperature	-40 - 100℃	±0.5℃	2	Ward; Doctors office	March; April
	Humidity	0 - 100%	±3%			March; April
	CO_2	0 - 5000ppm	±75ppm			March; April

In doctor's office, Environmental data logger was put on the wall to record temperature, humidity and Carbon Dioxide Concentration, see Fig 3.3(a); Thermometer was put on the top of the wardrobe which is 1.8m high, see Fig 3.3(b); In ward, Wind speed & wind temperature data logger and Environmental data logger were settled on the wall between the two beds, see Fig 3.3(c); Every equipment was set to record data in every 10 minutes.

(a) HCZY-1 in doctor's office

(b) Testo175 H1 in Nurse

(c) HCZY-1 and WFWZY-1 in double room ward

Figure 3.3 Placement of location.

3.2.2 Questionnaire

Participants involved in this research were selected randomly. A total of 168 effective questionnaires were collected in this research. They filled in Chinese version of questionnaire, which are attached in appendix section.

In this section, English version was presented. The questionnaire was divided into two parts. Their identity, types of room when they answered the questions, how many people were there in their room, clothing insulation, metabolic rate of activity level were included in Part One. In order to understand how people perceived the environments, participants were invited to answer their actual thermal sensation, their humidity sensation, their expectation of environments in Part two. Table 3.3 shows the questions and options of Part Two.

Table 3.3 Questions used for sensory and expectation.

	Question:	**Options:**
1.	Do you think it is cold or hot in hospital?	1. cold 2.slightly cool 3.cool 4.neutral

		5. warm 6.slightly warm 7.hot
2.	Do you want to get colder or warmer?	1.colder 2.do not change 3.warmer
3.	Do you think that the air is so dry or wet?	1. very wet 2. wet 3.slightly wet 4.neutral 5. very dry 6. dry 7.slightly dry
4.	Do you want to get drier or wetter?	1.wetter 2.do not change 3.drier
5.	What do you think of air speed?	1.no wind 2. slightly wind 3.clear wind 4.strongwind
6.	Do you want air speed to get weaker or stronger?	1.weaker 2.do not change 3. stronger
7.	What do think of the overall environment? (considering temperature, humidity and air speed)	1.very comfort 2.comfort 3.neutral 4.slight discomfort 5.very discomfort
8.	Is it acceptable for the current environment in hospital?	1.totally unacceptable 2.unacceptable 3.acceptable 4.totally acceptable

PMV and PPD are applied when people are in a constant environment and metabolic rate. Visitors and pregnant woman are temporary occupants for the hospital, for they stay here and leave after delivery; hospital is a permanently place for staff who work here during workdays more than 10 hours a day [57]. Therefore, before the participants wrote the questionnaire, the researchers would tell them to fill out the questionnaire based on what they perceived within 30 minutes.

3.3 Data processing

Before analyzing and discussing, it is necessary to explain the limitations and remedies in objective data collection and questionnaire delivery process. Pregnant women have a high demand for privacy and their duration of hospitalization is short. During hospitalization, the attention of the hospital staff, pregnant women and visitors lies in the smooth birth of the neonate and the recovery of the pregnant women. However, investigators lacked working experience in hospitals and had limited time for investigation, which made them hard to establish trust relationship with patients and their families in a short time. With the establishment of trust relationship between patients and their families, hospital staff would assist investigators in collecting subjective data from patients and their families. All participants finished the questionnaire in ward. The staffs were busy and they could not help to record the environmental parameters while collecting the questionnaire. The measurements were carried out as following:

- First of all, a ward was selected randomly and instruments were placed at the head of the bed, 1 meters from the ground. Environmental parameters were recorded in every 10 minutes.
- Participants wrote down the time when they were writing questionnaire.
- The average value of the environmental parameters within one hour of

the participants' answer time were referred to as the objective data.

The second limitation was the radiant temperature, because the volume of the black-bulb thermometer was too large to be placed in the ward for a long time. After several sampling investigations, the radiant temperature was almost equal to that of the black ball. Therefore, the air temperature was used to represent the radiate temperature in this survey [56].

3.3.1 Calculation for PMV

The widely used Comfort equation is recorded in ASHRAE standard[30] for stable environment:

$$PMV=[0.303\exp(-0.036M)+0.0275]\times\{M-W-3.05[5.733-0.007(M-W)-P_a]-0.42(M-W-58.2)-0.0173M(5.867-P_a)-0.0014M(34-t_a)-3.96\times10^{-8}f_{cl}[(t_{cl}+273)^4-(t_r+273)^4]-f_{cl}h_c(t_{cl}-t_a)\} \quad (3.1)$$

$$t_{cl}=35.7-0.028(M-W)-I_{cl}\{3.96\times10^{-8}f_{cl}\times[(t_r+273)^4]+f_{cl}h_c(t_{cl}-t_a)\} \quad (3.2)$$

$$h_c=\begin{cases}2.38(t_{cl}-t_a)^{0.25} & \text{for } 2.38\times|t_{cl}-t_a|>1.21\sqrt{V_{ar}}\\ 12.1\sqrt{V_{ar}} & \text{for } 2.38\times|t_{cl}-t_a|<1.21\sqrt{V_{ar}}\end{cases} \quad (3.3)$$

$$f_{cl}=\begin{cases}1.00+1.290\times I_{cl} & \text{for } I_{cl}\leq0.078m^2K/W\\ 1.00+0.645\times I_{cl} & \text{for } I_{cl}>0.078m^2K/W\end{cases} \quad (3.4)$$

The variables which are mentioned above are defined as:

M: is metabolic rate, in Watts per square meter of the body surface area, W/m^2

W: is effective mechanical power, in Watts per square meter, equal to zero for most activities, W/m^2

I_{cl} :is thermal resistance of clothing, in square meters degree Celsius per Watt, m^{2}K/W

f_{cl}: is ratio of surface area of the body with clothes to the surface area of the body without clothes

t_a: is air temperature, in degree Celsius, ℃

t_r: is mean radiant temperature, in degree Celsius, ℃

V_{ar}: is relative air velocity, in meter per second, m/s

P_a: is water vapor partial pressure, in Pascal

h_c: is convective heat transfer coefficient, in Watts per square meter degree Celsius, W/(m^2*K)

t_{cl}: is clothing surface temperature, in degree Celsius, ℃

Eight variables are included in those equations mentioned above. f_{cl} and t_{cl} are determined by I_{cl}; h_c is related to air velocity; W is 0.

PMV represents how the vast majority of people perceive in the same environment, so it can be used to evaluate a comfortable environment or not. However, the individual differences are existed between people, so it is possible to apply PMV to identify whether all people feel comfort or not. Therefore, Fanger [38] proposed Predicted Percentage Dissatisfied (PPD) to represent the percentage of dissatisfaction of the thermal environment:

$$PPD=100-95\exp\left[-\left(0.03353PMV^4+0.2179PMV^2\right)\right] \quad (3.5)$$

In this research, Excel will be used to calculate PMV and PPD values by inserting these formulas. The method can be found in ISO 7730 [58] and Built Environment [38].

3.3.2 Data processing

In the study of thermal comfort, it is widely applied successive temperature bins rather than individual votes to perform the relationship between operative temperature and PMV values and TSV values. The operative temperature is divided into several intervals at interval of 0.5 °C [59]. The average operative temperature in each operative temperature interval is used as an independent variable. The average value of the respondent's thermal sensation votes in one interval is referred to as dependent variable. The relationship between the subjective thermal sensation of the human body and the indoor operating temperature is:

$$TSV=a+b*t\_op \quad (3.6)$$

Where is:

TSV: thermal sensation vote; t_op: is operative temperature, ℃;

a,b: constant.

TSV to be 0 is referred as neutral sensation when people neither feel hot nor feel cold. If TSV is 0, the subjective neutral operative temperature can be calculated.

In the same way, the objective neutral temperature can be calculated. In addition, the relationship between acceptable temperature, wind speed and thermal comfort are determined based on this method as well. This method will be presented again before data analysis. In addition, a certain amount of researches have adopted this method to reflect the relationship between the operative temperature and other variables [10, 14, 56].

ET, ET* and SET are also applied to describe how environment affect thermal sensation. These three variables represent the value of air temperature in standard environment, which combine effects of the other environmental parameters on thermal comfort. Zhu [38] summarized the limitation of these index on her book. ET is overestimated in terms of the effect of temperature on cooling and comfort under low temperature conditions. ET* has been improved based on ET, which is introduced the concept of skin moisture. But ET* is only applied to the conditions of low wind speed, small activity and light clothing. By analyzing heat transfer of human body, SET is proposed to denote the effect of various clothing, metabolic rate of activity and environmental variables on human body sensation. It is complex to calculate SET, because the skin temperature and skin moisture are included in calculating SET. Therefore, the universality of SET application is limited. Comparing ET, ET* and SET, this research will use operative temperature to indicate the relationship between the environment and thermal sensation.

The operative temperature is a weighted average of indoor air temperature and average radiation temperature, which can reflect the comprehensive effect of convection and radiate heat transfer. The calculation method is shown in equation (3.7):

$$t\_op=\frac{h_c t_a+h_r t_r}{h_c+h_r} \tag{3.7}$$

Where is:

t_op: is operative temperature, ℃

h_c: is convective heat transfer coefficient, W/(m^2*K)

t_a: is air temperature, ℃

t_r: is mean radiant temperature, ℃

h_r: radiative heat transfer coefficient, W/（m^2 ·℃）

According to domestic standards, Equation 3.8 can be used for those whose metabolic rate is between 1.0-1.3met and who are not exposed to direct air exposure to the surrounding air (no more than 0.2m/s):

$$t\_op=\frac{t_a+t_r}{2} \tag{3.8}$$

Secondly, Two-sample t-tests were conducted for thermal sensation to determine the difference between the average value of thermal sensation obtained from objective and from subjective measurements on a 5% level. ANOVA were used to compare whether there were significant differences in terms of PMV and TSV among different identities, different window-opening behaviors, different room types and different surrounding people on a 5% level.

Chapter 4 Results and discussion

In this chapter, both objective result and subjective result will be displayed. First of all, daily and hourly variations of environmental parameters will be shown; secondly, subjective and objective thermal sensation values will be compared; thirdly, this research will apply variance analysis to evaluate whether there are differences between months and identities.

4.1 Objective data

This section will be divided into two parts including the daily changes and the hourly changes. To compare the daily environmental differences in different rooms and outdoor, these figures will be plotted first. Then hourly changes of each rooms will be plotted to observe whether the indoor environments are steady followed by.

The number of measurement parameters are shown on Table 4.1.

Table 4.1 Total number of measurement parameters.

	March		April	
	Measurement parameters	**Total number of datasets**	**Measurement parameters**	**Total number of datasets**
Ward	Relative Humidity, Air temperature, carbon Dioxide, Velocity	3488	Relative Humidity, Air temperature, carbon Dioxide, Velocity	5692
Office	Relative Humidity, Air speed, carbon dioxide	2616	Relative Humidity, Air temperature, carbon Dioxide, Velocity	4269

Nurse Station	Not applicable	-	Relative Humidity, Air temperature	2846
Outdoor	Not applicable	-	Relative Humidity, Air temperature	2846

For daily figures, the value of each point showing in figures was calculated by the average of 144 data collected in that day. The average of six data collected within an hour was hourly value.

4.1.1 Daily Variation of measurement data

Table 4.2 presents the domestic standard for maternity ward at the domestic level. Generally, it is recommended that the air temperature for hospital should be between 28-26℃, the relative temperature should be between 40-60% and the air velocity should be around 0.12 m/s.

Table 4.2 Standards of domestic hospital design.

Standard for hospital	**Department**	**Recommended temperature/ ℃**	**Recommended humidity/ RH%**	**Velocity m/s**
JGJ49-88 [54]	In-patient area for pregnant women	22~26	-	-
	Doctor's office, Nurse Station	18~20	-	-
GB 50139 [53]	Newborn room	22~26	40-60%	0.12
JGJ26-2010 [60]	Residential building in winter	18	-	-

4.1.1.1 Air temperature

According to Figure 4.1, indoor temperature remained stable in March. During the test period, the range of air temperature in doctor's office was 24.52 to 25.69 °C and the range in ward was 25.39 to 26.91 °C. Outdoor temperature rose steadily with slightly fluctuations and temperature change range was 0.3 to 5°C. From the overall comparison, indoor air temperature difference was 0.70 to 2.06 °C; indoor and outdoor temperature difference was bigger, which the maximum temperature difference was 25.70 °C, the minimum temperature difference was 21.00 °C.

Figure 4.2 shows the average indoor air temperature and outdoor temperature in April. The trends of indoor air temperature in April were similar to the change in March. The air temperature ranges in ward, doctor's office and nurse station are 26.42~28.84°C, 24.71~28.25°C and 24.29~26.57°C respectively. Compared to that in the ward, the air temperature in doctor's office and nurse station were slightly lower. However, the outdoor temperature change was pronounced. From April 22 to April 29, the average outdoor temperature gradually increased. On April 29, the temperature was the highest of the test period, which was 25.19 °C. Then the temperature dropped sharply to 16.95 °C on May 2. Overall, the outdoor temperature did not affect the indoor air temperature.

The previous research [10] shows that patients preferred a warmer environment and the indoor air temperature in this hospital is higher than the domestic standard [61]. In addition, the indoor air temperature in this hospital is warmer than other thermal comfort research [40] conducted in the same area. Therefore, this hospital created a comfortable environment for the occupants.

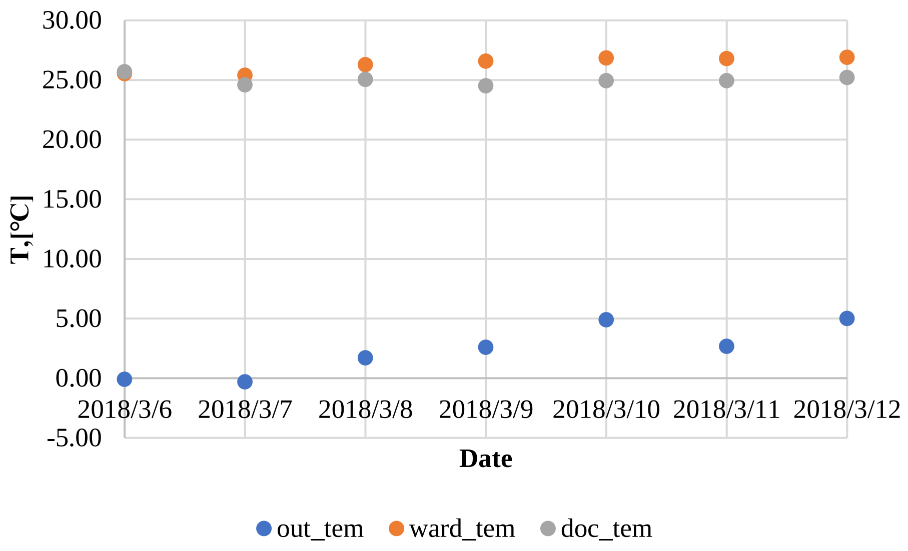

Figure 4.1 Air temperature recorded in ward(ward_tem), doctor office(doc_tem) and outdoor temperature(out_tem) in March.

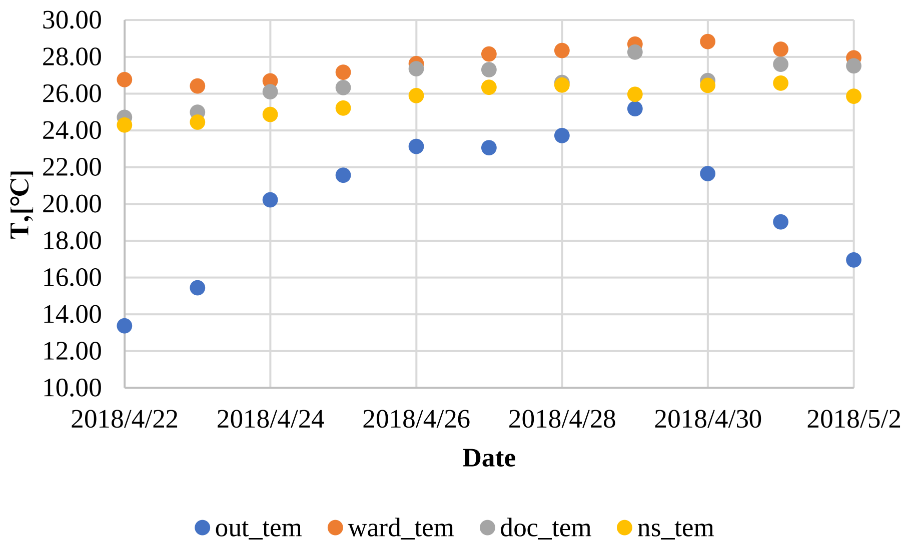

Figure 4.2 Air temperature recorded for ward(ward_tem), doctor office(doc_tem) and nurse

station(ns_tem), compared to the outdoor temperature(out_tem) in April.

4.1.1.2 Relative humidity

The trends of relative humidity in ward, doctor's office, nurse station and outdoor recorded in March and April are shown in Figure 4.3 and Figure 4.4 respectively. The variation range of outdoor humidity in March was at 37-59% and the average value was 46.29%; the relative humidity in the ward ranged from 32.11 to 42.40% with an average of 38.19%; the relative humidity in the doctor's office ranged from 25.44 to 38.43% with average of 31.26%. In April, the range of outdoor humidity was at 35.48-65.07% with average value of 49.39%; the variation range of relative humidity in the ward was 43.75-56.24% and the average value was 48.42%; the relative humidity in the doctor's office was at 32.66-50.77% with average of 41.71%; the relative humidity at the nurse station ranged from 42.16% to 64% with average of 50.34%.

There is no humidity design standard for maternity department and doctor's office in domestic level [53]. By referring to humidity standard in other department, care unit should remain its RH throughout the year at 40 ~ 60%, blood ward in winter is not less than 45% and the summer is not higher than 60%, burn ward in winter is not less than 45% and the summer is not higher than 60%, it can be concluded that the relative humidity requirements of maternity wards should meet no less than 40% in winter and no higher than 60% in summer. In addition, according to the domestic survey [21] on thermal comfort for hospitals, the relative humidity in hospitals should be at 40 - 60%. In conclusion, for this study, it can be inferred that the ward and doctor's office were slightly dry in

March and the environment in April was suitable.

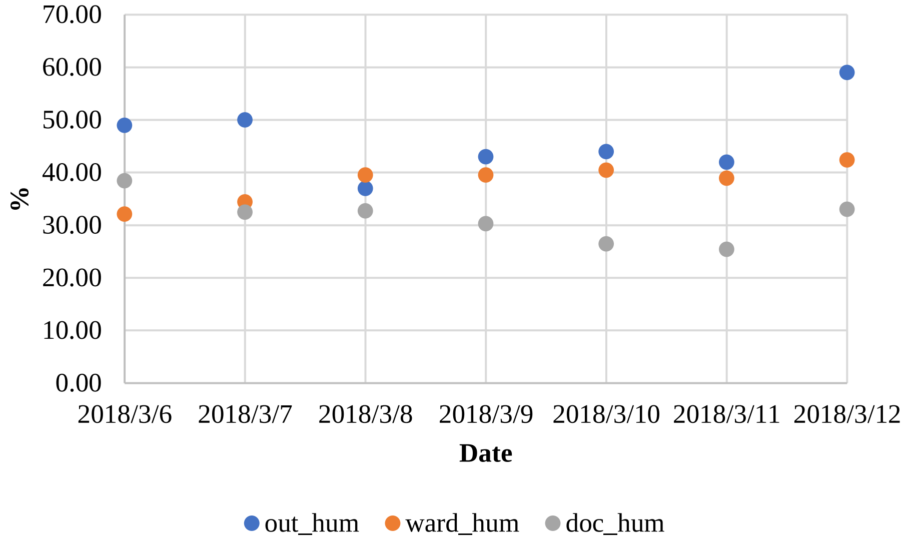

Figure 4.3 Relative humidity recorded for ward(ward_hum) and doctor office(doc_hum), compared to the outdoor humidity(out_hum) in March.

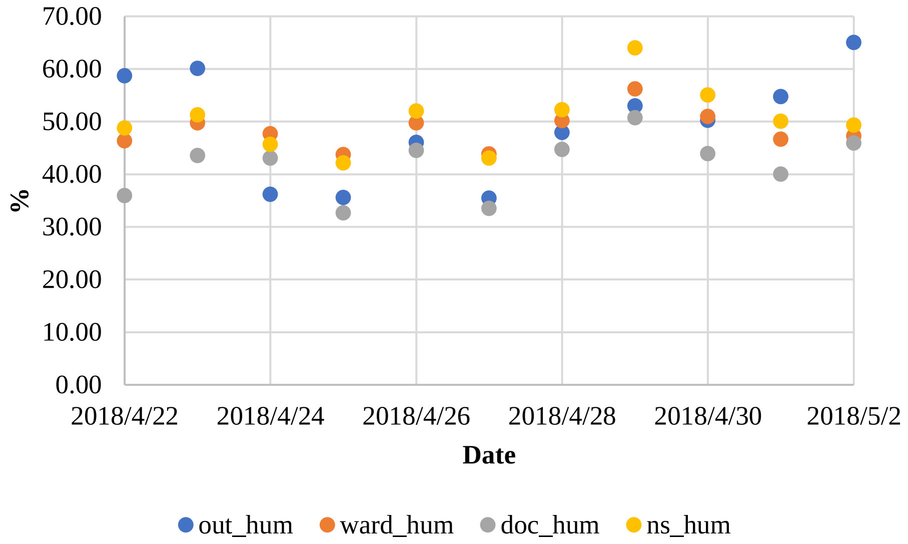

Figure 4.4 Relative humidity recorded for ward (ward_hum), doctor office (doc_hum) and nurse station (ns_hum) compared to the outdoor humidity (out_hum).

4.1.1.3 Air Velocity

As shown in Figure 4.5, the air velocity in March ranged from 0 to 0.03m/s and the average value was 0.02m/s; Figure 4.6 displays the air velocity changes in April, which ranged from 0.01~0.06m/s with average of 0.03m/s. Both in March and in April, the air velocity was extremely low. According to the domestic standard [53], when patients receive treatment or do some exercise, the air velocity should be higher than 0.2 m/s; when they have a rest, the air velocity should be higher than 0.12 m/s. The air velocity should be strengthened in this hospital.

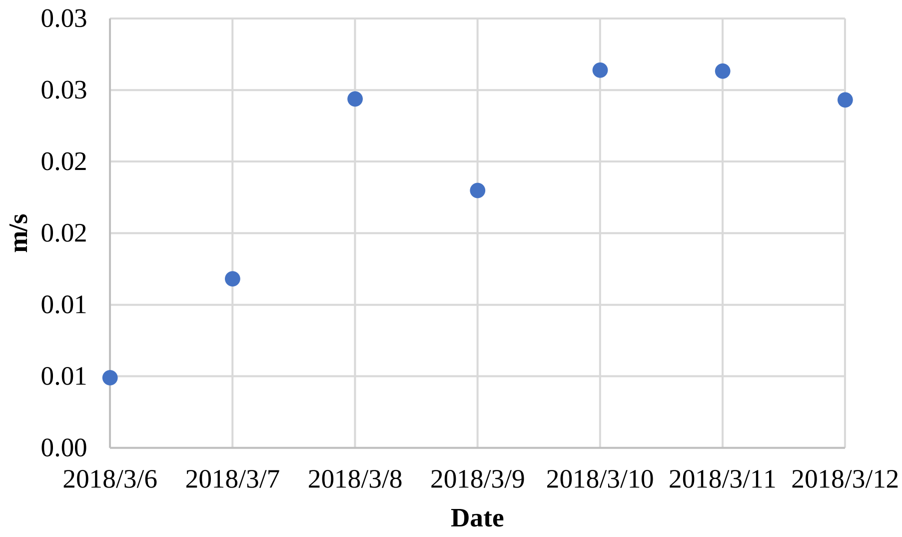

Figure 4.5 Air velocity recorded for ward in March.

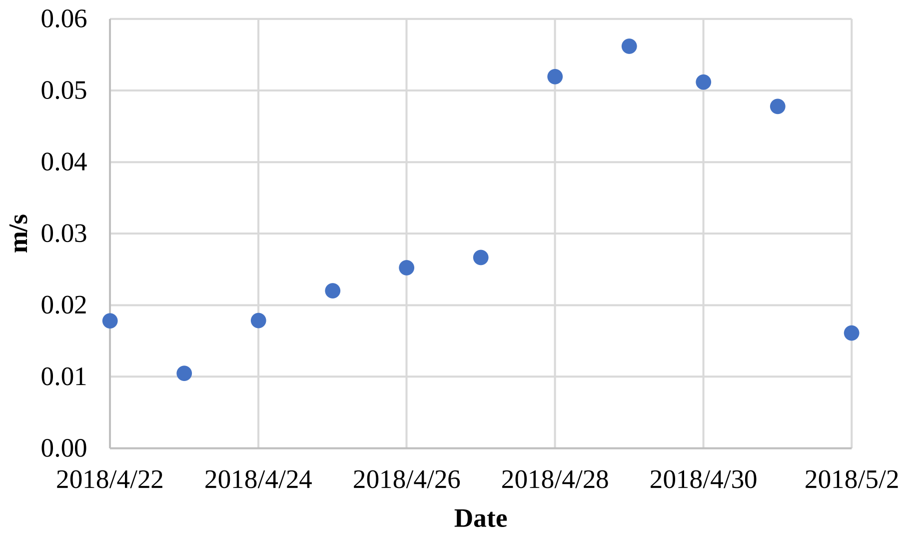

Figure 4.6 Air Velocity recorded for ward in April.

4.1.1.4 Carbon Dioxide

The measurements of concentration of Carbon Dioxide in ward and doctor's office show that the concentration of CO_2 in ward was obviously higher than the doctor's office, which were all much higher than 1000ppm [62]. 1000ppm was the upper limit of indoor CO_2 concentration. In March, the range of CO_2 concentration in ward was 1447.83~2011.10ppm with average of 1709.70 ppm; the distribution of CO_2 concentration in the doctor's office was from 706.44 to 1817.88 ppm with an average of 1127.44 ppm. In April, the CO_2 concentration in the ward ranged between 1093.66 and 1660.33 ppm with an average of 1313.30 ppm; in the doctor's office, the CO_2 concentration ranged from 513.69 to 1316.00 ppm with an average of 724.84 ppm. The results show that the difference in the CO_2 concentration between the doctor's office and the ward was 582.27 ppm and 588.47 ppm in March and April respectively, indicating that the concentration of the ward was far higher than that in the doctor's office.

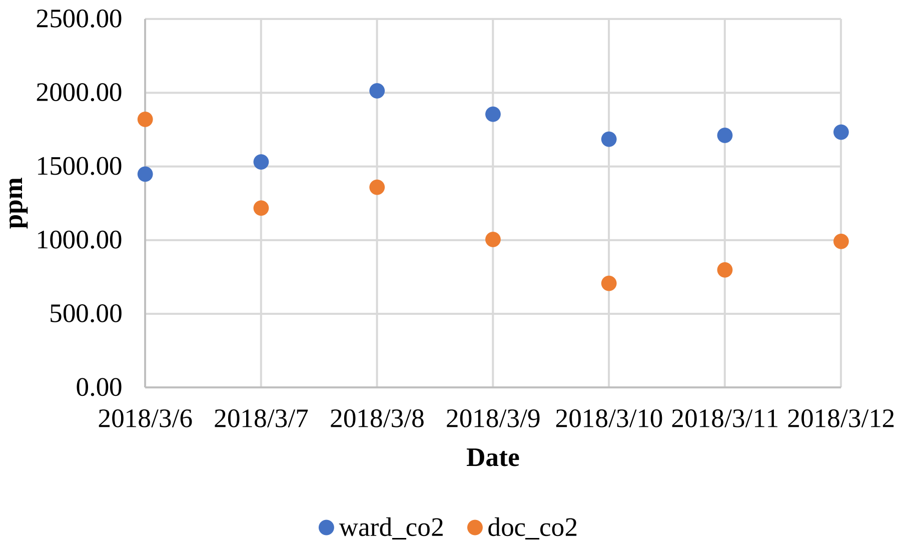

Figure 4.7 Carbon dioxide recorded for ward(ward_CO_2) and doctor office(doc_CO_2) in March.

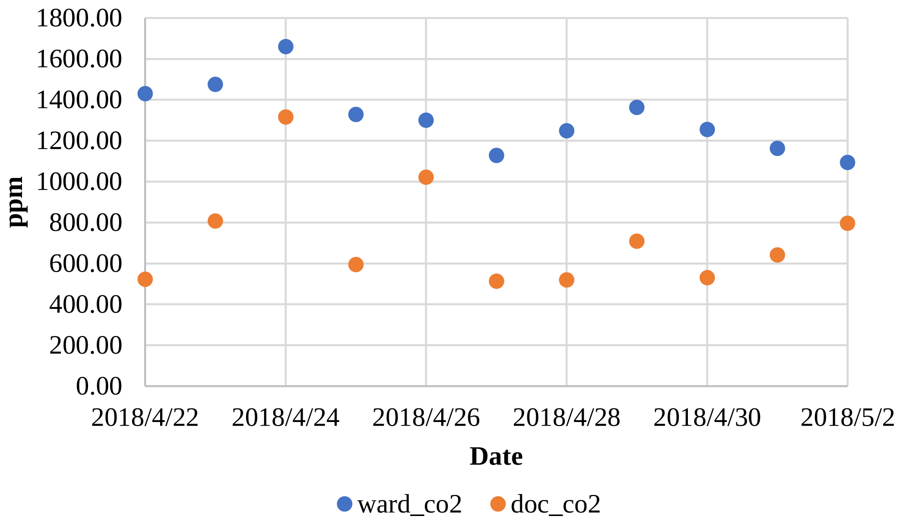

Figure 4.8 Carbon dioxide recorded for ward(ward_CO_2) and doctor office(doc_CO_2) in April.

4.1.2 Hourly Variation of environmental parameters

The purpose of this section is to investigate whether the indoor environment in this hospital was at relatively steady state. This section is divided into two parts to introduce the hourly changes in terms of indoor and outdoor environment. The indoor environmental parameters including air temperature, relative humidity, air velocity and carbon dioxide concentration, which will be shown in turn; then outdoor changes will be shown followed by. Outdoor parameters included air temperature and relative humidity.

4.1.2.1 Indoor air conditions

4.1.2.1.1 Air temperature

As shown in Figure4.9-4.13, the hourly air temperature in hospital was relatively stable and fluctuated slightly within a certain range in both March and April. In ward, the daily air temperature differences of the average were 1.61 ℃ and 1.32℃ in March and April respectively. In doctor's office, the daily air temperatures difference of the average were 2.73℃ and 2.27℃ in March and April respectively. At nurse station, the air temperature difference was 1.92℃. Such small temperature differences indicate that the air temperature of hospital did not change so much.

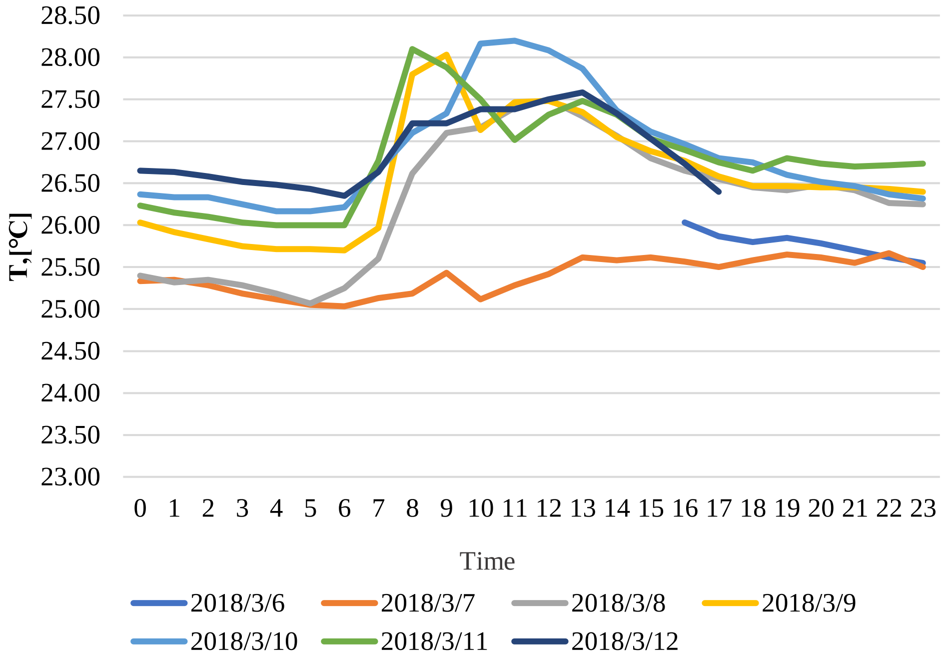

Figure 4.9 Air temperature recorded for ward in March.

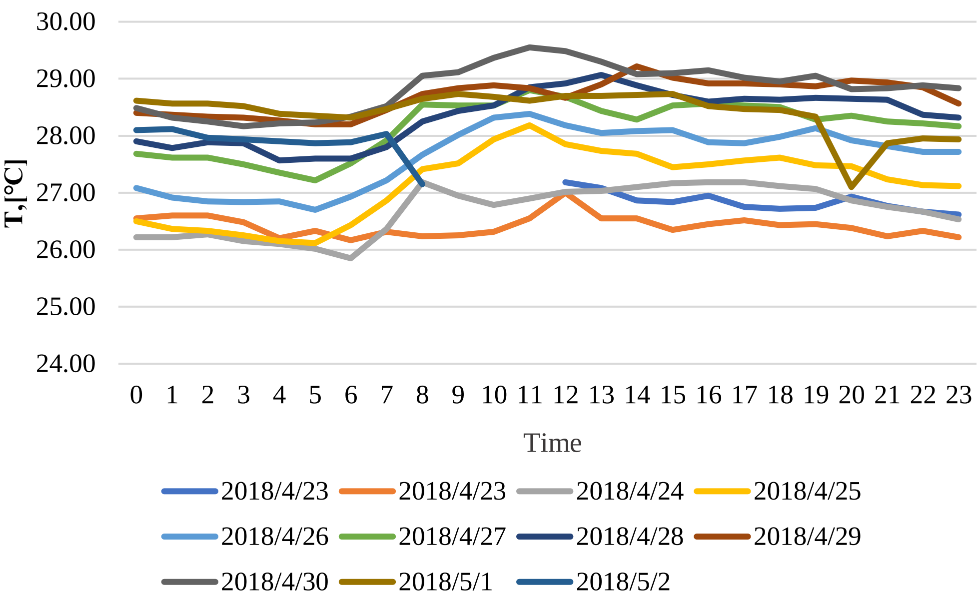

Figure 4.10 Air temperature recorded for ward in April.

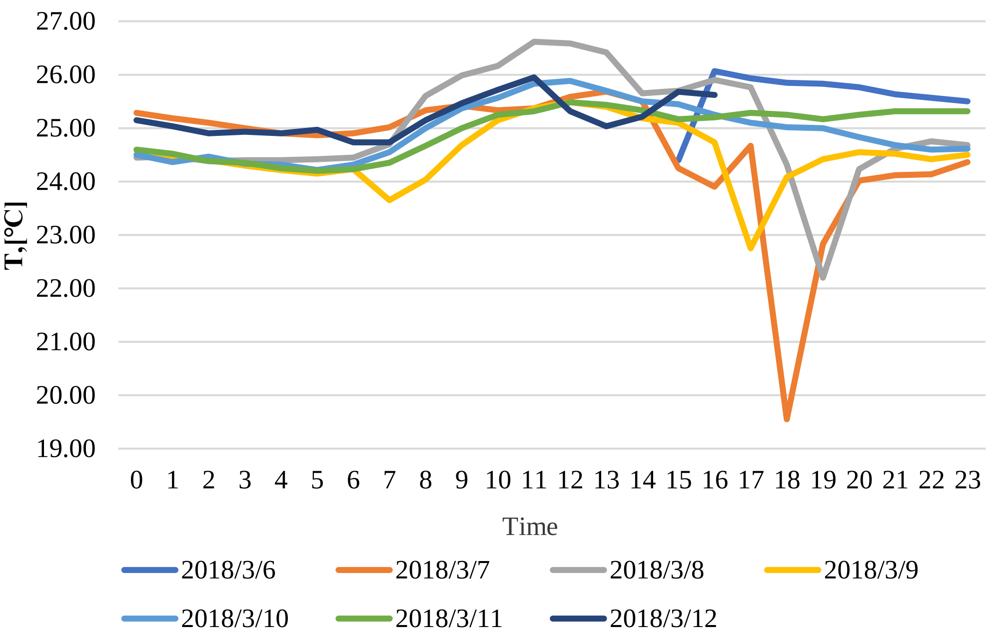

Figure 4.11 Air temperature recorded for Doctor's office in March.

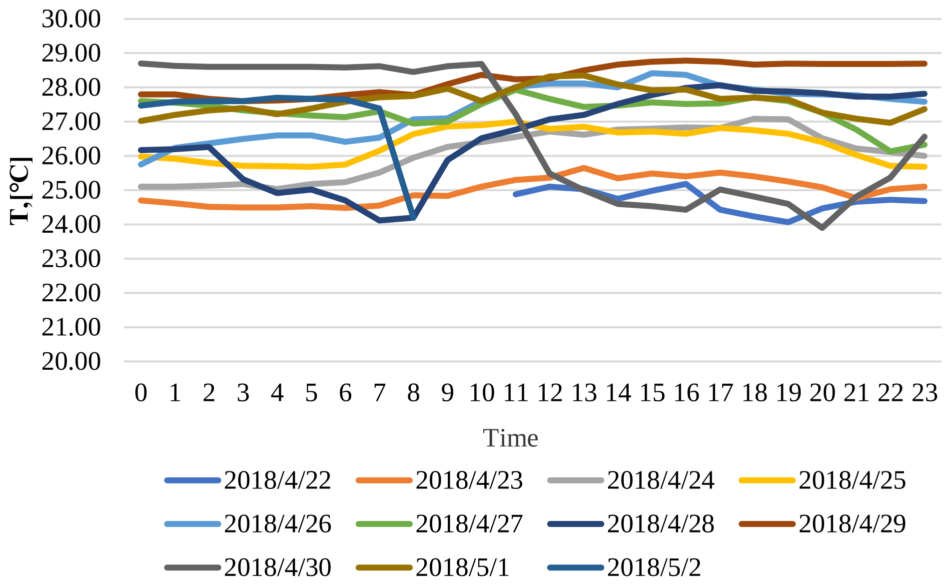

Figure 4.12 Air temperature recorded for Doctor's office in April.

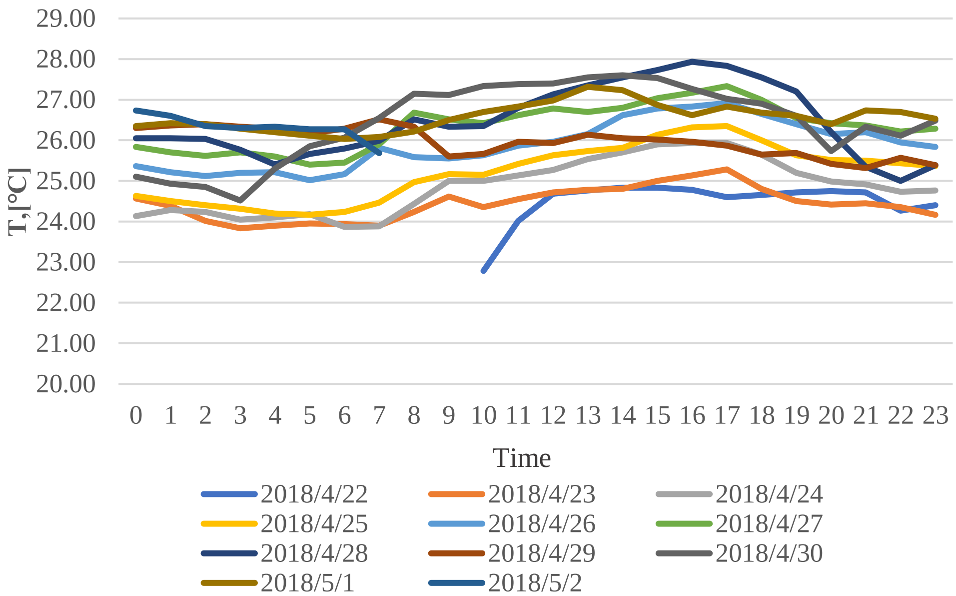

Figure 4.13 Air temperature recorded for nurse station in April.

4.1.2.1.2 Relative humidity

From Figure 4.14 to Figure 4.18, these figures show the hourly trends of the indoor relative humidity of ward and doctor's office in March and April. The relatively humidity fluctuated within the fixed interval. Although the changes in the fixed interval sometimes are slightly large, the relative humidity for each room were at reasonable levels which recommended by domestic standard (shown on Table 4.2). It is necessary to indicate that the hospital was still relatively dry in some days.

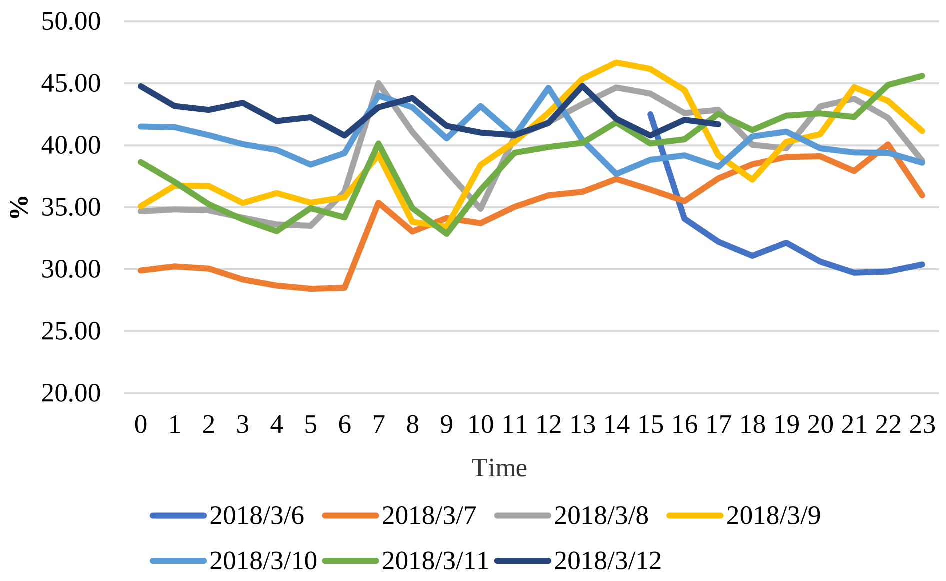

Figure 4.14 Relative Humidity recorded for ward in March.

As shown in Figure 4.14, in heating month, relative humidity in ward in March ranged from 28.50 % to 46.68%, which represented slightly dry. Especially on March 6, the first day of observation, it kept dropping from 42.50% to 30.37%; on March 7, the whole day, the relative humidity values were under 40.00%. On March 8, March 9 and March 11, from 0 to 11 o'clock, the relative humidity kept increasing over 40.00%. The relative humidity values of other time were over 40.00%.

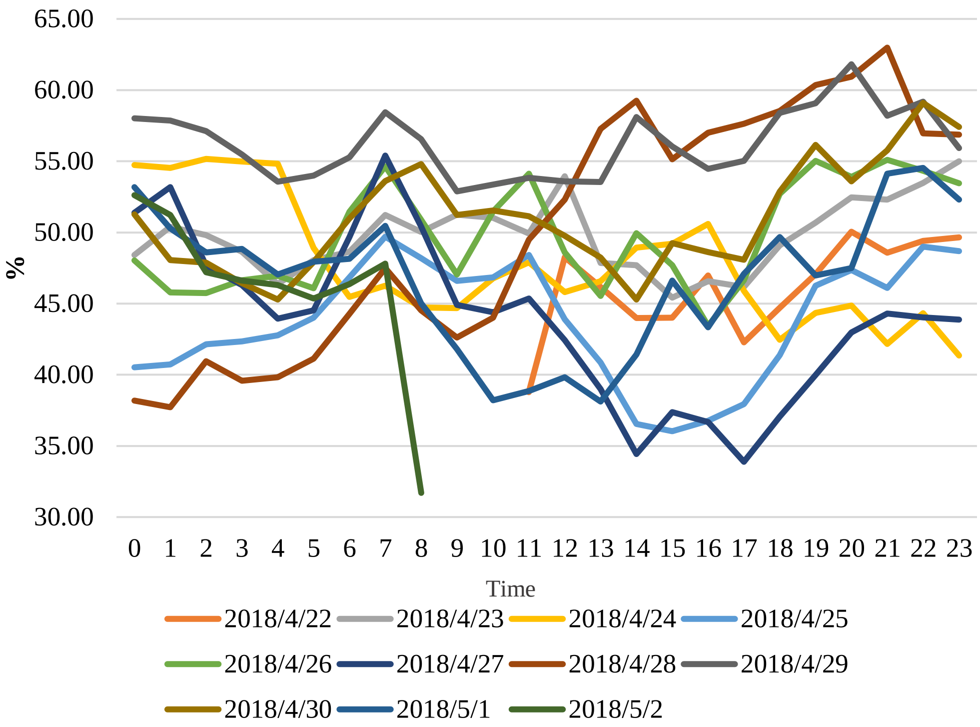

Figure 4.15 Relative humidity recorded for ward in April.

The relative humidity in ward in April were over 40.00% except 1-3 pm on April 25, 1-7 pm on April 27 and 10 am to 14 pm on May 1. It indicates that the humidity condition in April could meet the requirement. (Figure 4.15)

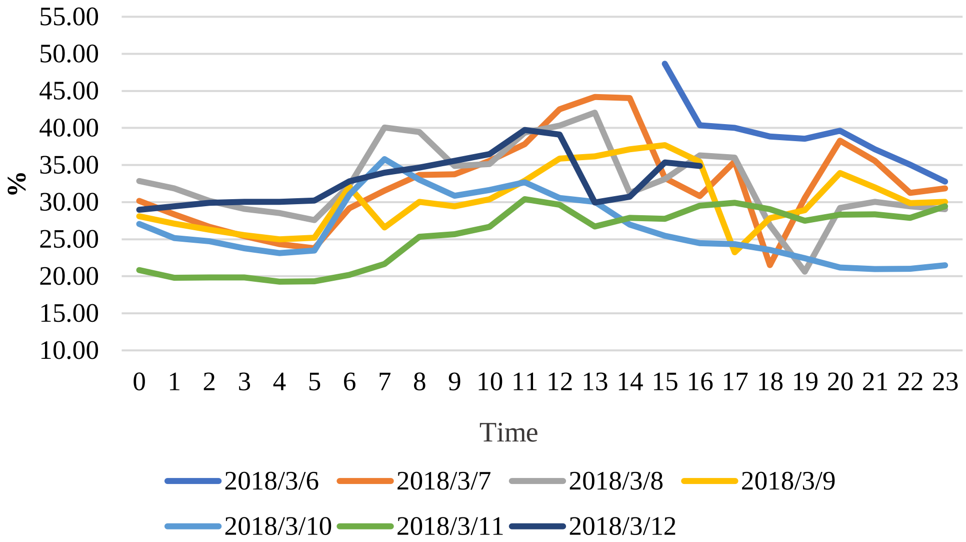

Figure 4.16 Relative humidity recorded for doctor's office in March.

The relative humidity in doctor's office in March were little drier than the standard. As shown in Figure 4.16, it was only at 12-15pm on March 7 when the relative humidity reached the standard. (figure 4.16)

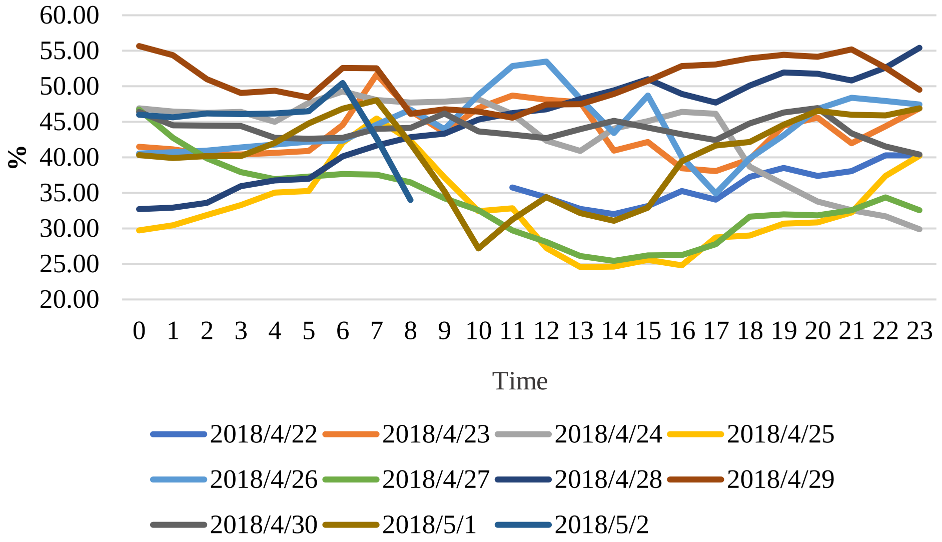

Figure 4.17 Relative humidity recorded for doctor's office in April.

Figure 4.17 shows the relative humidity recorded in doctor's office in April. Compared to March, the indoor relative humidity became wetter in the ventilation season.

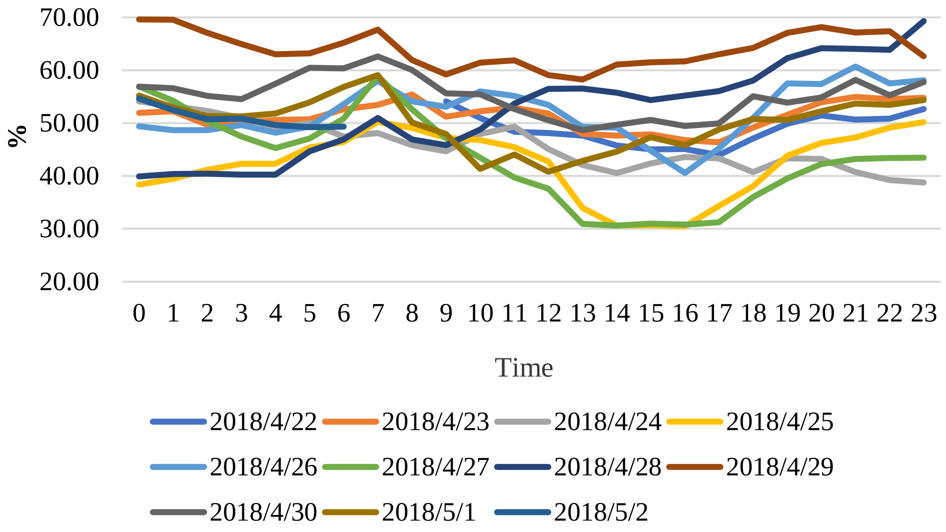

Figure 4.18 Relative humidity recorded for nurse station in April.

Compared to the ward and the doctor's office, the nurse station is an open place. Only at 12 pm to 6 pm on April 25 and April 27, the indoor relative humidity of nurse station was slightly dry. (Figure 4.18)

4.1.2.1.3 Air velocity

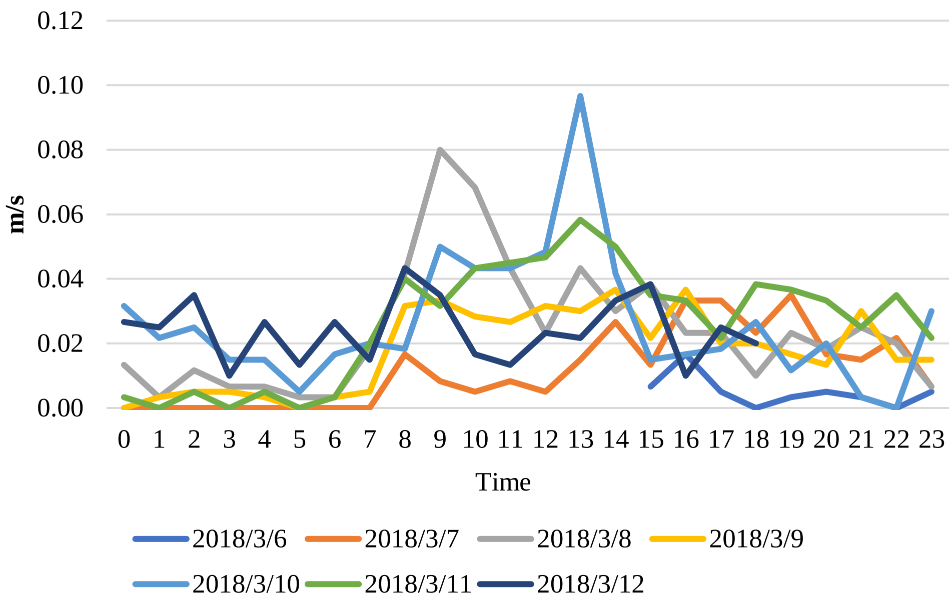

Figure 4.19 Air Velocity recorded in ward in March.

Figure 4.19 shows the changes of indoor air velocity in ward from 0 to 23 pm in March in the period of observation. The air velocity in ward fluctuated from 0 to 0.06m/s every day. This might fail to meet the requirements of 0.12m/s mentioned in the standard. Therefore, the air velocity in the hospital is needed to be strengthened.

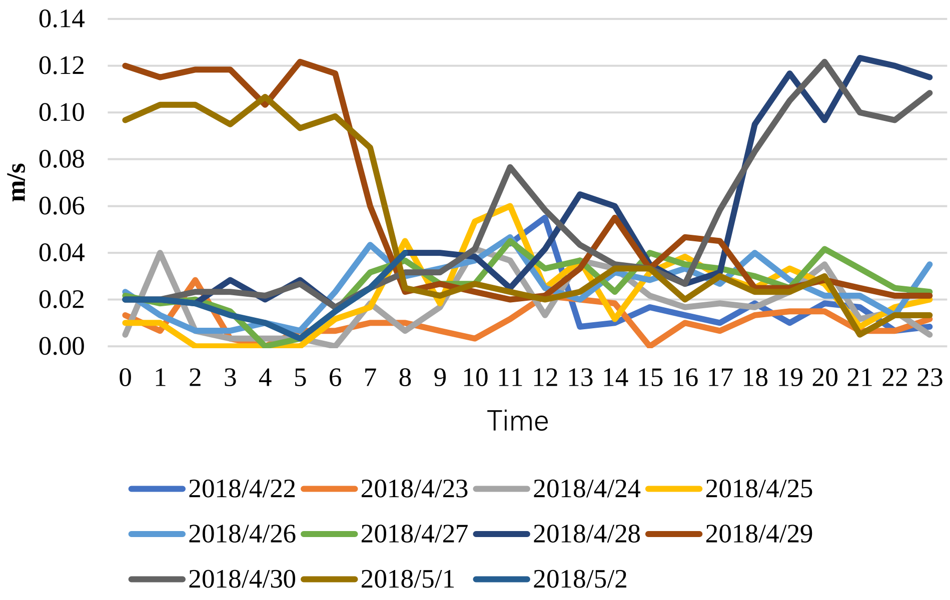

Figure 4.20 Air velocity recorded in ward in April.

Figure 4.20 shows the changes of indoor air velocity in ward from 0 to 23 in April. The indoor air velocity in ward kept fluctuating within the range from 0 to 0.06m/s and the maximum air velocity was 0.08m/s. Only on April 28 and 30 April, the air velocity gradually rose to 0.12 m/s since 5 pm and remained to next 7 am; then the value of air velocity in ward decreased below 0.04 m/s.

4.1.2.1.4 Carbon Dioxide

In ward, both in April and in March, the values of concentration of Carbon Dioxide were higher than 1000ppm. In March, Indoor carbon dioxide concentrations reached the top of the day around 12 pm to 2 pm; in April, the concentration of Carbon dioxide fluctuated frequently and presented irregular changes. (Figure 4.21 and Figure 4.22)

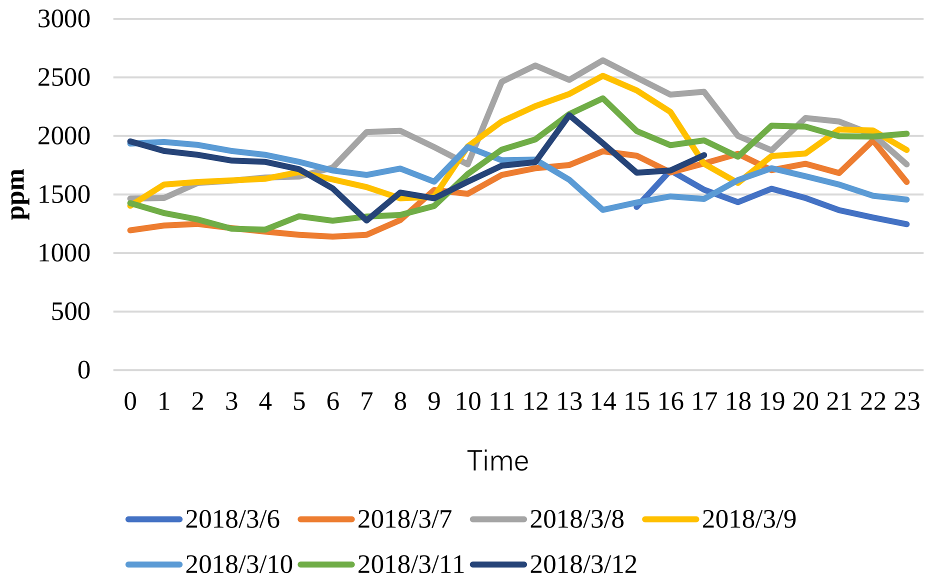

Figure 4.21 Carbon dioxide recorded in ward in March.

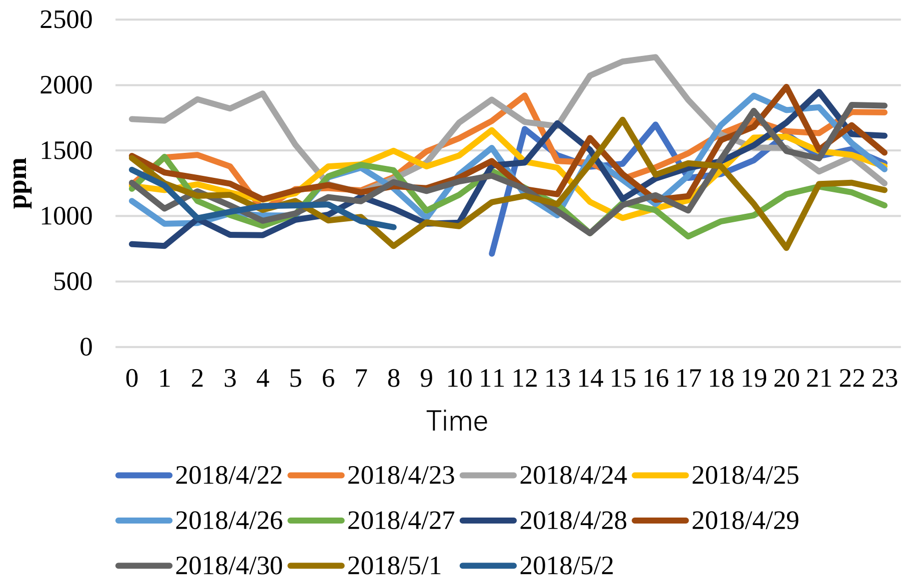

Figure 4.22 Carbon dioxide recorded in ward in April.

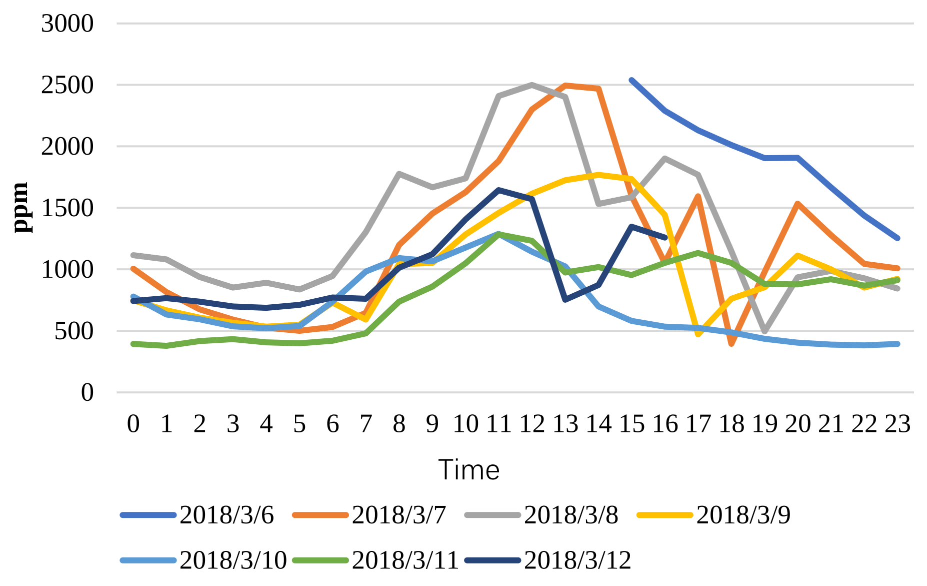

Figure 4.23 Carbon dioxide recorded for doctor's office in March.

As shown in Figure 4.23, the carbon dioxide variation diagram presented a normal distribution in March. From 0 to 7 am, the concentration of Carbon Dioxide remained stable; then the concentration of CO_2 went up to the peak till noon; after 12 pm, it kept dropping to 23 pm.

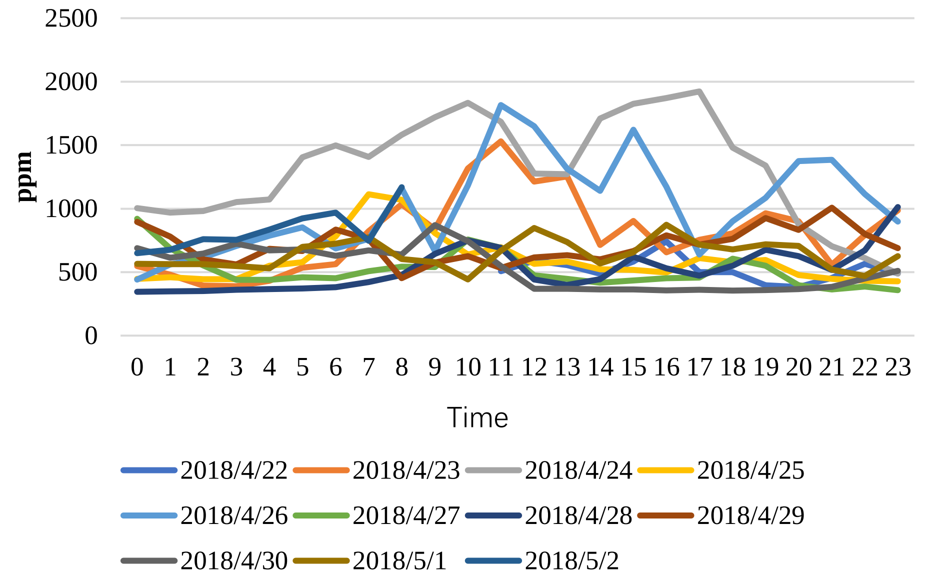

Figure 4.24 Carbon dioxide recorded for doctor's office in April.

On April 23, April 24 and April 26, the values of carbon dioxide concentration in doctor's office were higher than 1000 ppm. Carbon dioxide concentration was less than 1000 ppm in other days, which represented the concentration of carbon dioxide returning to normal. (Figure 4.24)

4.1.2.2 Outdoor air conditions

The outdoor temperature and humidity in March were not recorded by measurement sensors in March due to the measurement failure. Outdoor temperature and humidity data which were from China Air Quality Online Monitoring and Analysis Platform were used as follows.

4.1.2.2.1 Air Temperature

Figure 4.25 and Figure 4.26 show the continuous trends of outdoor temperature of 24 hours during the field work. The trends of March were significantly difference from April. In March, from 1 am to 6 am, outdoor temperature decreased to the lowest temperature of a day. After the temperature rose continuously to the highest around 4 pm, it began to drop rapidly till midnight. In April, it was quite different from the changes in March. The trends of every 24 hours were normal distributions. After a slightly drop to the lowest temperature of a day at 6 am, it kept up rapidly till 13-14pm, then it continuously dropped till midnight.

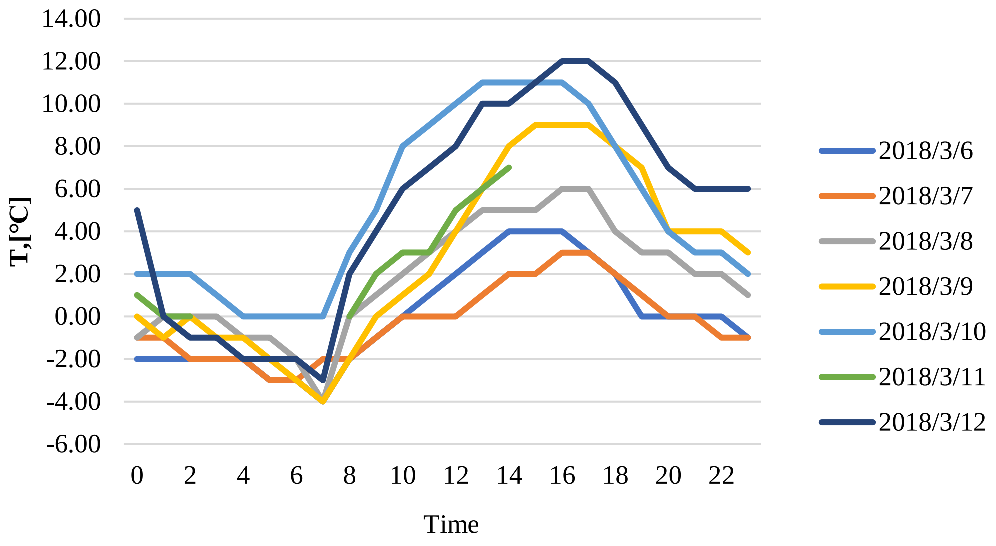

Figure 4.25 Average outdoor temperature change in 24 hours in March per hour.

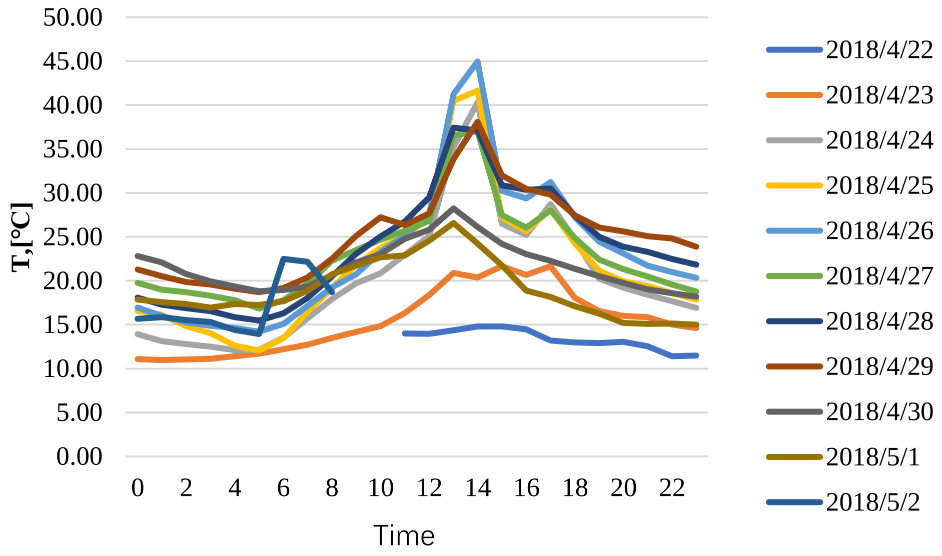

Figure 4.26 Average outdoor temperature change in 24 hours in April per hour.

4.1.2.2.2 Outdoor Humidity

The 24-hour outdoor temperature changes in March and April were similar, showing a 90-degree counterclockwise rotating S-shape.

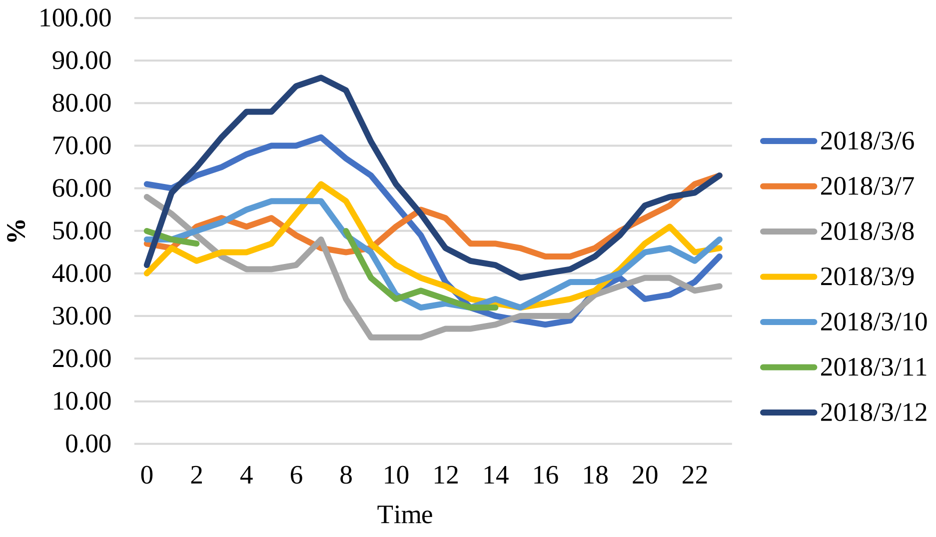

Figure 4.27 Average outdoor humidity in March per hour.

In March, except for March 7th, the value of humidity started to rise from 0 to 7 am when reached the highest value in a day before it began to drop to the lowest of the day till 3 pm; then the outdoor humidity slowly rose until the end of the day. Outdoor humidity ranged from 25.00 to 86.00 % in March. (Figure 4.27)

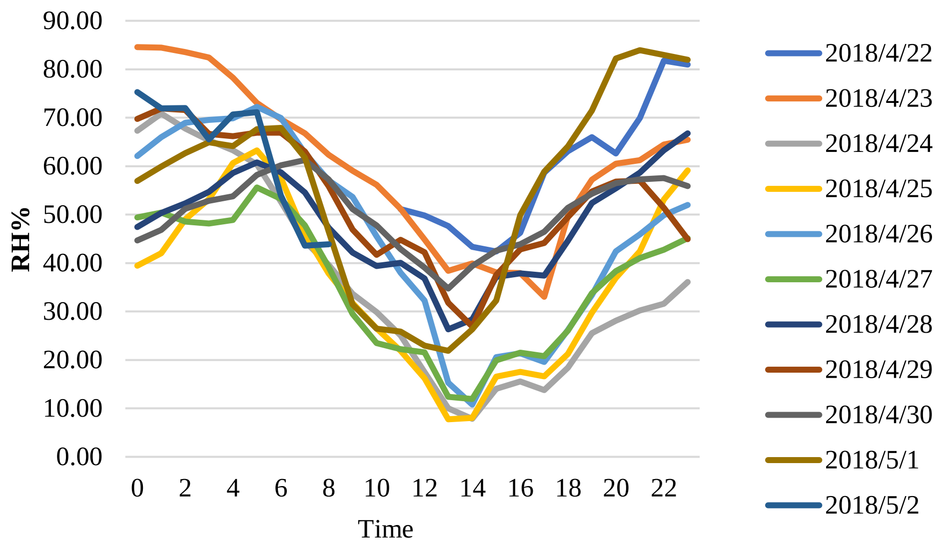

Figure 4.28 Average outdoor humidity in April per hour.

As shown in Figure 4.28, except for April 23, the time of the day when the outdoor humidity was the lowest was usually at 2 pm and the highest temperature in a single day was found at 2 pm (Figure 4.26). Generally, the change of outdoor humidity in April could be divided into three stages: 0-5am, outdoor humidity rose slowly; 5 am - 2 pm, outdoor humidity dropped to the lowest of that day; after 2 pm, the outdoor humidity gradually increased.

In conclusion, the indoor climate figures in March and April show that:

- Indoor air temperature kept basically steady during two separate observation periods;
- Indoor relative humidity in March was slight dry; it was wet in April;
- Indoor air velocity was low both in March and in April.
- The concentration of carbon dioxide indicated that the hospital should take steps to enhance the indoor quality. Low air velocity led the

concentration of carbon dioxide.

4.2. Personal factors

The basic information on sample size, identity and number of surrounding people are shown in Table 4.3. This research included 168 effective questionnaires, which were collected from 68 pregnant women, 83 visitors and 17 staff; 41 of them were from March and 127 were from April. Most of participants were pregnant women and visitors and they lived in double room or triple room. The mean number of surrounding people was more than four.

Table 4.3 Basic information.

		Pregnant woman	**Visitor**	**Staff**	**Total**
Sample size	**-**	68	83	17	168
Type of room	**Single room**	6	2	-	8
	Double room	33	24	1	58
	Triple room	30	46	3	69
	Else	9	11	13	33
Month	**March**	12	23	6	41
	April	56	60	11	127

Number of surrounding people	**One**	2	2	-	4
	Two	19	7	-	26
	Three	13	21	5	39
	Four	17	25	1	43
	Five or more	17	28	11	56

4.2.1. Clothing insulation (clo)

Standard from domestic requirements[63] of clothes insulation is shown on Table 4.4. According to this, clothing is quantified with clo units.

Table 4.4 Clothing insulation (clo).

	Clothing	Clothing insulation	Clothing	Clothing insulation	Clothing	Clothing insulation
Coats	**Down jacket**	0.55	**Dust coat**	0.40	**Sports coat**	0.30
	Jackets	0.25	**Sweater**	0.25	**vest**	0.15
Shirts	**Pajamas**	0.20	**Long blouse with long sleeves**	0.20	**Light blouse with long sleeves**	0.15
Trousers	**Light trousers**	0.20	**Padded pants**	0.30	**Normal trousers**	0.25
	Long johns	0.20	**Shorts**	0.10		
Skirts, dresses	**Light skirt**	0.10	**Thick long skirt**	0.20	**One-piece dress**	0.20

Socks	**Socks**	0.02	**Long socks**	0.05	**Leather shoes/ sports shoes**	0.10
	cotton slippers	0.05	**Slippers**	0.02		

Table 4.5 presents the statistical overview of clothing resistance. The clothing insulation was 1.13clo and 0.81clo in March and April respectively. From the perspective of identity, the average of thermal resistance of visitor (0.91clo) was greater than that of pregnant woman (0.88 clo) and greater than that of staff (0.84 clo). There was no remarkable difference in clothing insulation between different room types and different number of surrounding people.

Table 4.5 Statistical overview of the thermal resistance (clo).

		Sample size	Max	Mean	Min
Month	**March**	41	1.47	1.13±0.20	0.62
	April	127	1.87	0.81±0.26	0.33
	overall	168	1.87	0.89±0.28	0.33
Identity	**Pregnant woman**	68	1.87	0.88±0.29	0.35
	visitor	83	1.47	0.91±0.27	0.33
	Staff	17	1.47	0.84±0.33	0.34
	Overall	168	1.87	0.89±0.28	0.33
Room type	**Single**	8	1.19	0.88±0.24	0.41
	Double	58	1.87	0.90±0.32	0.33
	Triple	69	1.47	0.91±0.26	0.37

	Else	33	1.31	0.80±0.28	0.34
	overall	168	1.87	0.89±0.28	0.33
Number of surrounding people	**One**	4	1.23	0.88±0.44	0.44
	Two	26	1.87	0.90±0.32	0.39
	Three	39	1.47	0.99±0.27	0.35
	Four	43	1.40	0.90±0.29	0.33
	Five and above	56	1.31	0.80±0.24	0.33
	overall	168	1.87	0.89±0.28	0.33

4.2.2. Metabolic rate of different activity level (met)

Table 4.6 shows the metabolic rate of common activity based on GB/T 50785[63]. Table 4.7 illustrates the metabolic rate of this survey. Comparison shows that there was no big difference in metabolic rate, which was 1.21met and 1.26met respectively, between March and April. Most of pregnant women sat on the chair, walked around or just stood; due to the limitation space of ward, the visitors usually stood, walk around or sat down when there were not many people staying in the ward; however, the staff, they had to switch to different rooms to make sure every pregnant woman was in good situation. Compared with the pregnant women and the visitors, the metabolic rate of the staff was higher among three. The metabolic rate of different activity levels varied from different types of room. The metabolic rate of people staying in the single room was the highest, which was 1.34 met. It was followed by else room, double room, triple room with 1.31clo, 1.23clo and 1.21clo respectively. It illustrates that the number of people staying in the room also affected activity levels. When five or above people were staying with participants, the metabolic rate would be 1.36

met, which was 0.11 ,0.16, 0.17 and 0.22 met higher than one people, four people, three people and two people respectively. Therefore, single room created a space for people moving; more people surrounding you may promote people to have a higher activity level.

Table 4.6 Metabolic rate of each activity levels.

Activity level	Metabolic rate (met)
Sleep	0.7
Lay on the bed	1.0
Sit	1.2
Stand, Relax	1.4
Stand, Slightly activity	1.6
Stand, Moderate activity; walk 2 Km/h	1.9
Stand, walk occasionally	2.1

Table 4.7 Average activity levels (met).

		Sample size	Max	Mean	Min
Month	**March**	41	2.10	1.21±0.53	0.80
	April	127	1.90	1.26±0.35	0.70
	Overall	168	2.10	1.25±0.40	0.70
Identity	**Pregnant woman**	68	2.10	1.11±0.37	0.70
	visitor	83	2.10	1.29±0.38	0.80
	Staff	17	2.10	1.59±0.38	1.00
	Overall	168	2.10	1.25±0.40	1.00
Room type	**Single**	8	2.10	1.34±0.45	0.70
	Double	58	2.10	1.23±0.41	0.70

	Triple	69	2.10	1.21±0.37	0.70
	Else	33	2.10	1.31±0.43	0.70
	Overall	168	2.10	1.25±0.40	0.70
Number of surrounding people	**One**	4	1.40	1.25±0.19	1.00
	Two	26	2.10	1.14±0.36	0.70
	Three	39	2.10	1.19±0.42	0.70
	Four	43	1.90	1.20±0.40	0.70
	Five and above	56	2.10	1.36±0.40	0.70
	Overall	168	2.10	1.25±0.40	0.70

4.3. Thermal sensation

Based on the results obtained from subjective and objective measurement results, we found thermal sensation is variable due to different conditions, such as season and identity of occupants. This result is important to illustrate the factors influencing the thermal sensation and therefore would be very useful for achieving a better design of maternity hospital in terms of thermal comfort.

This part will be divided into two parts: 1. presenting both subjective thermal comfort and objective thermal comfort; 2. comparing the subjective thermal comfort in terms of different dimensions.

For the first section, in order to investigate the variation between subjective thermal sensation and objective thermal sensation, data from 168 effective questionnaires was pooled together across different months, different identities, different room types, as well as different number of surrounding people.

In addition, the subjective humidity sensation will be analyzed, which used a similar methodology to the subjective thermal sensation.

For the second section, these issues will be discussed:

- Differences in thermal comfort between March and April will be discussed due to the different operating mode. In March, the hospital was operated by central heating system; in April, natural ventilation was applied.
- The time length for stay in hospital of pregnant woman, visitor and staff are different. Thus, this may lead to different thermal comfort. Comparing the general time length, it shows that the staff work in maternity hospital almost all year around indicating the time they stay in hospital is longer than the pregnant women and the visitors. As proved by Hwang[10], different time length may lead different thermal sensation based on their adaption. Therefore, it is worth to focus on the thermal comfort differences of different groups of participants.
- Thermal comfort differences may be existed due to the different number of surrounding people and room type.

4.3.1. Evaluating thermal sensation based on overall data

4.2.1.1. PMV and Thermal Sensation Vote (TSV)

The subjective thermal sensation vote is based on traditional ASHRAE 7-point scale[30], participants should answer how they perceive the environment according to their actual feeling by choosing -3,-2,-1,0,1,2,3. These points correspond cold, cool, slightly cool, neutral, slightly warm, warm and hot.

The objective thermal comfort vote is calculated according to PMV model. The observed results are similar to the subjective thermal sensation vote, which -3= cold, -2=cool, -1= slightly cool, 0= neutral, 1=slightly warm, 2= warm, 3= hot. Figure 4.29 and Figure 4.30 show the distribution of the subjective and the objective thermal comfort, which were from the subjects' rating and the calculation through PMV equation.

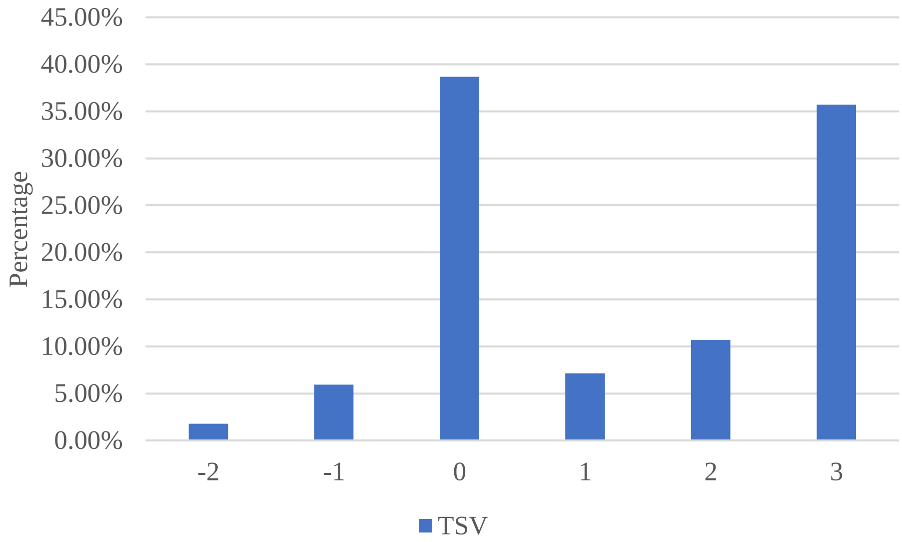

Figure 4.29 Frequency distribution of TSV in hospital.

As shown in Figure 4.29, 38.69% of participants chose neutral, which indicated they felt comfort in maternity hospital; then 35.71% of participants argued that the climate of hospital was hot; the percentage of people who felt warm was 10.71%; 7.14%, 5.95% and 1.79% of the total population chose slightly warm, slightly cold and cold respectively.

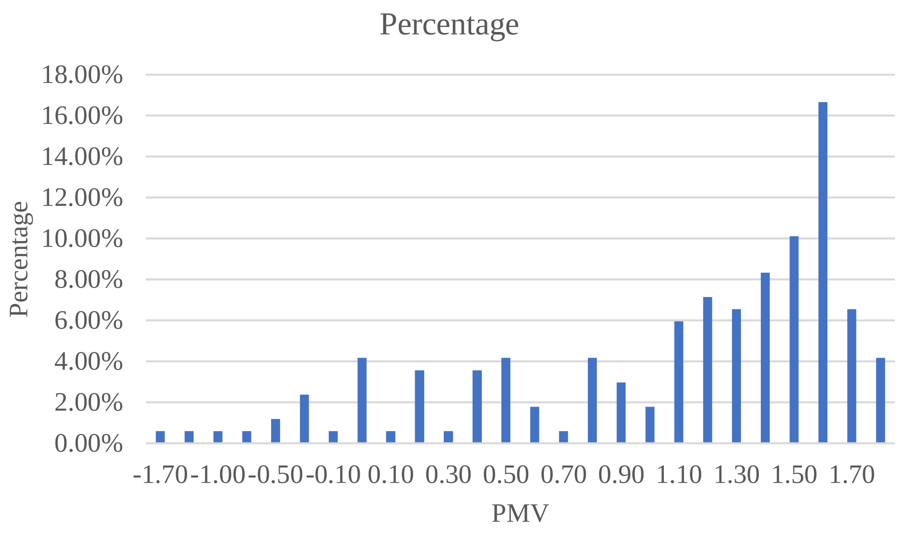

Figure 4.30 Frequency distribution of PMV in maternity hospital.

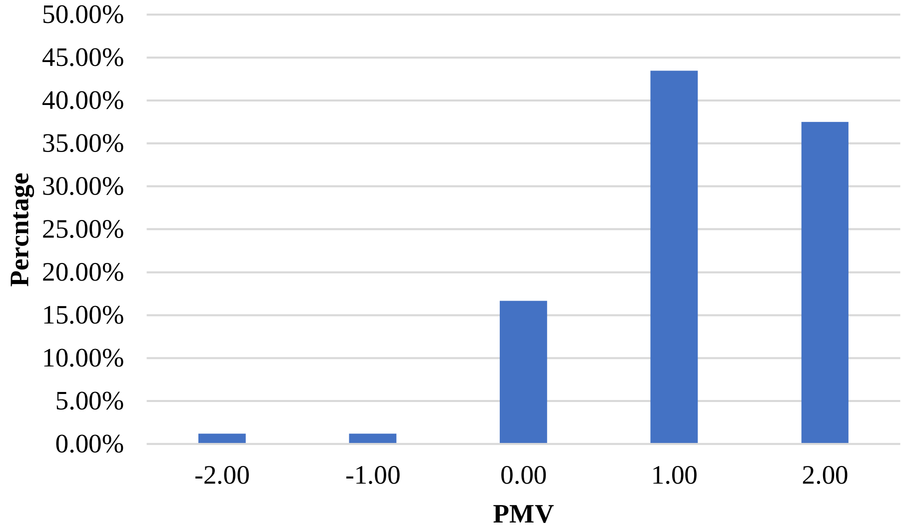

Figure 4. 31 Frequency distribution of PMV in hospital after grouped.

The Figure 4.30 and 4.31 shows the frequency distribution of PMV in maternity hospital. It predicts that 61.3% of participants perceived comfort because their predicted rating was from -1 to 1. From objective perspective, it is clear that the environment in this hospital did not reach 85% satisfaction which formulated on

ASHRAE standards[30], but the rate of satisfaction of objective thermal sensation was higher than the subjective.

The relationship between subjective, objective thermal comfort and operative temperature are shown in Figure 4.33. Before Figure 4.33, it is necessary to illustrate the operative temperature intervals at first.

The distribution of number of interviewees in each operative temperature interval is shown in the Figure 4.32. The operative temperature intervals were included in this survey: 25.5-25.9℃， 26.5-26.9℃， 27-27.4℃， 28-28.4℃ and 28.5-28.9℃.

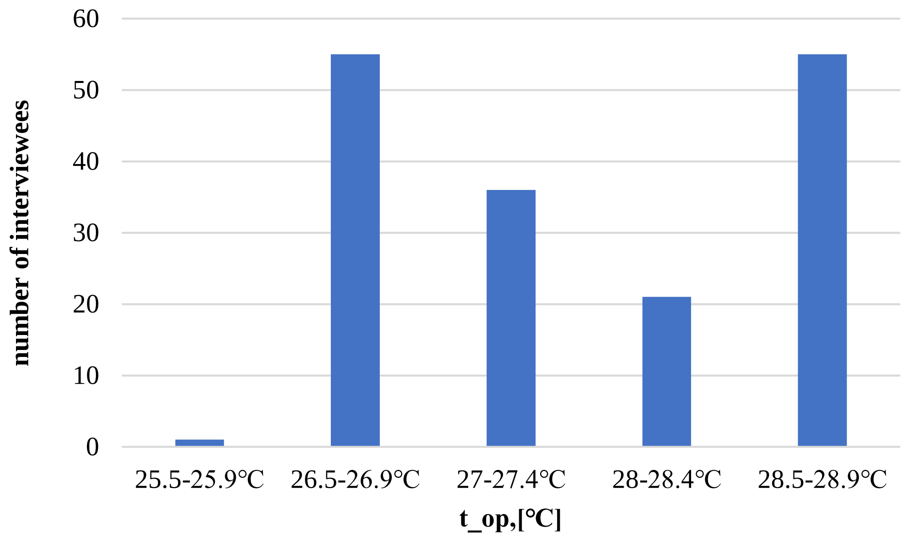

Figure 4.32 The number of interviewees in each operative temperature interval.

Only one sample was included within the range of 25.5-25.9℃, which was not representative. Therefore, this sample would be ignored when applying operative temperature to calculate neutral operative temperature, acceptable operative temperature and other index to reduce the error caused by this sample.

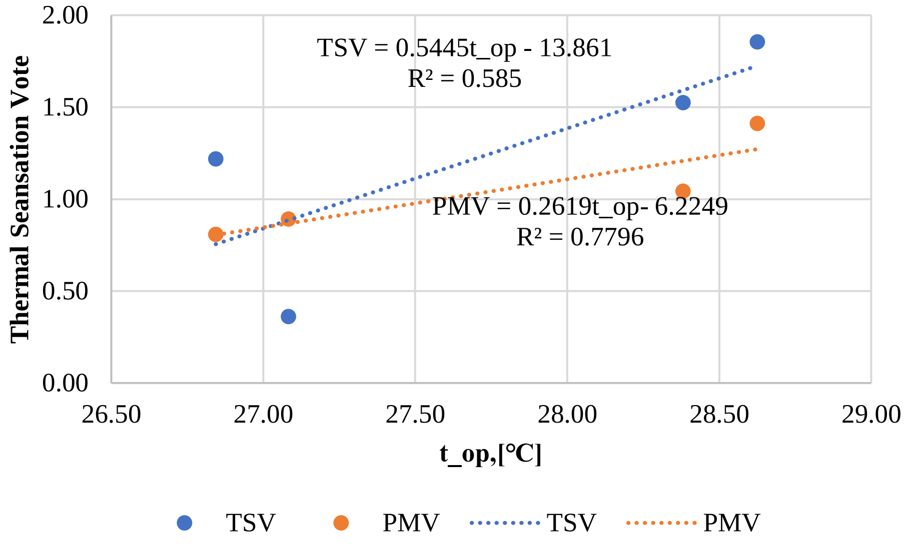

Figure 4.33 Comparison between TSV and PMV.

The method to draw Figure 4.33 is shown as follows, which also mentioned in Methodology Chapter. The operative temperature was divided into several intervals at intervals of 0.5 °C. The average operative temperature of the whole samples at the one intervals was taken as an independent variable. The average thermal sensation vote of all respondents within the 0.5°C operative temperature bin was taken as the dependent variable. The linear regression analysis was carried out to obtain the linear relationship between the actual thermal sensation and the operate temperature as Equation 3.6. When TSV=0, it indicates the moderate feeling to the environment and the neutral operative temperature can be observed. The linear regression between PMV and operative temperature can be obtained by the same proceeding. The linear equation between the objective sensation and the operative temperature is:

$$PMV = c + d * t\_op \quad (4.1)$$

Where

PMV is: objective thermal sensation vote;

t_op is: operative temperature;

c,d is: constant.

The calculated predicted thermal neutral temperature can be obtained when PMV equals to zero.

The subjective and objective thermal neutral operative temperatures are the ones leading to zero TSV and PMV respectively. The subjective and the objective thermal neutral temperature are calculated based on the correlation equations shown in Fig. 4.33. They are 25.46℃ and 23.77℃ respectively in the maternity hospital. This is also proving that the subjective thermal sensation is warmer than the objective thermal sensation.

According to Figure 4.33, the value of subjective and objective thermal comfort of human body increased with the increase of operative temperature. There was a “Scissors difference” between the TSV and the PMV regression, which indicating that the deviation between subjective thermal sensation and PMV prediction was greater with the increase of indoor operate temperature. People felt warmer than the predicted sensation. However, the finding of this research was not consistent with Fanger's. After Fanger et al. [64] summarized the surveys conducted in non-air-conditioned buildings in Bangkok, Singapore, Athens and Brisbane, they argued that the actual sensibility of thermal comfort of individuals was colder than the predicted sensation. They used the slopes of the TSV and PMV to demonstrate "Scissors difference". Cao et al.[65] also conducted a field work in terms of "Scissors difference" in Beijing under air-conditioned condition, which argued that people's subjective thermal comfort was higher than the calculated one due to the lack of adaption to warmer indoor environments in winter. In this research, as shown in Figure 4.33, when occupants wear proper clothing with certain metabolic rate of activity level, and their objective thermal sensation rate is higher than zero, which indicates it was unnecessary to maintain higher indoor temperature. Therefore, comparing to the previous study, this research may also advise hospital to create a low temperature environment for occupants because it not only could help to comfort the people in hospital but also help to reduce energy consumption in heating season.

Comparing to the domestic research conducted by Xia[66] whose finding demonstrated that the thermal neutral temperature for residential occupants in Beijing was 26.7 ℃, the neutral operative temperature for hospital habitants was slightly low. Thus, the indoor temperature should be a little lower in the hospital for hospital occupants.

Paired t-test was applied to test the differences between the TSV and the PMV. P-value was 0.101 ($P<0.05$) which indicates that there was no difference in trends between the TSV and the PMV. As shown in the Figure 4.34, the linear regression between the PMV and the TSV indicated that when PMV is neutral, the TSV value is 1.57. R^2 is 0.5989, which statistically shows low correlation between subjective thermal comfort and objective thermal comfort. But it still shows that people would feel a little warmer than predicted thermal comfort.

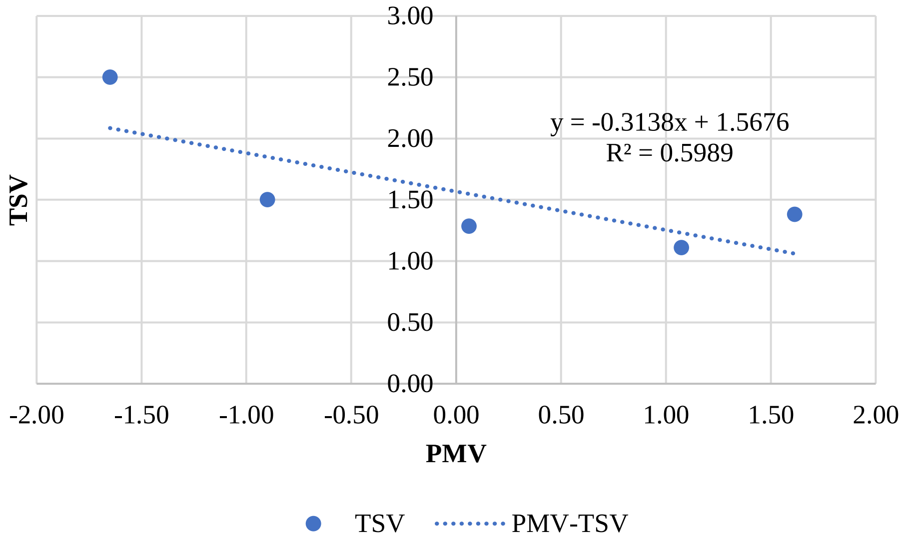

Figure 4.34 The relationship between PMV and TSV.

4.2.1.2. Activity levels

Figure 4.35 shows the average metabolic rate of different activity levels within 0.5°C operative temperature bin. The metabolic rate rose with the increase of operative temperature. However, the change of metabolic rate is slight. It is clear that people would not to change their behavior frequently in maternity hospital.

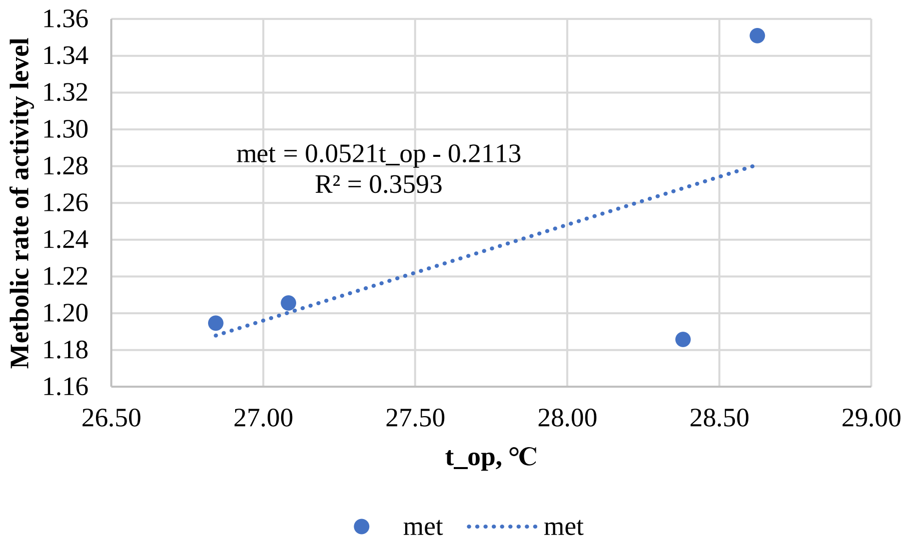

Figure 4.35 Linear regression between metabolic rate of activity level and operative temperature.

The metabolic rate of all samples was grouped at intervals of 0.5 met; the average value of each group was taken as an independent variable; the TSV and the PMV values within 0.5 met bin was averaged as a dependent variable. The result is shown in Figure 4.36.

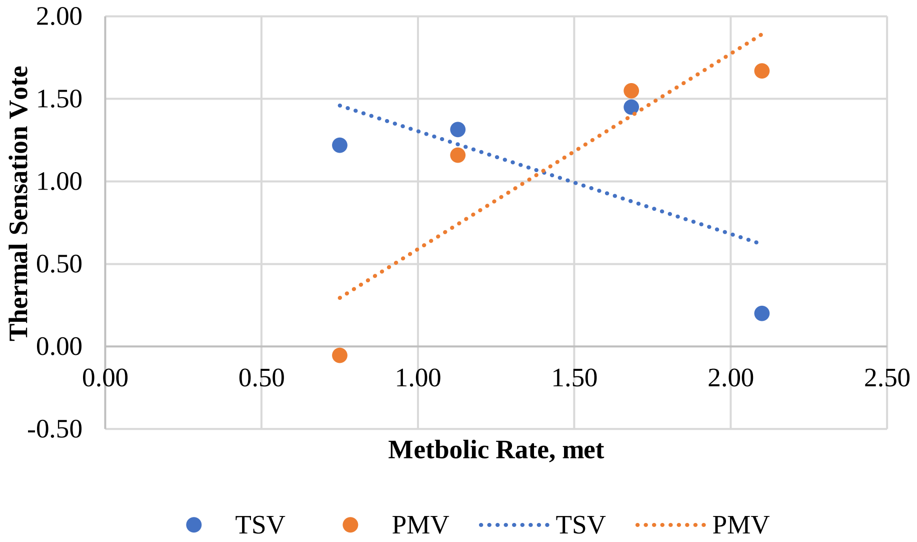

Figure 4.36 Correlation between Metabolic rate of activity level and TSV, PMV.

As shown in Figure 4.36, participants may feel cooler with the increase of metabolic rate according to their subjective vote; however, PMV value would rise with the increase of metabolic rate. This determined that people may improve their activity level to adapt the thermal conditions. PMV model clarifies that there is a positive relationship between metabolic rate and PMV value.

4.2.1.3. Clothing insulation

The Figure 4.37 shows the linear regression between the operate temperature and the average clothing insulation within 0.5℃ operative temperature bins. Generally, people would wear less clothes with the increase of operative temperature. Clothing had a strong correlation between operative temperature, R^2=0.62. In Figure 4.38, clothing insulationof all samples was grouped at intervals of 0.5 clo; the average value of each group was taken as an independent variable; the TSV and the PMV values within 0.5 clo bin was averaged as a dependent variable. (1clo=0.155m^2*K/W)

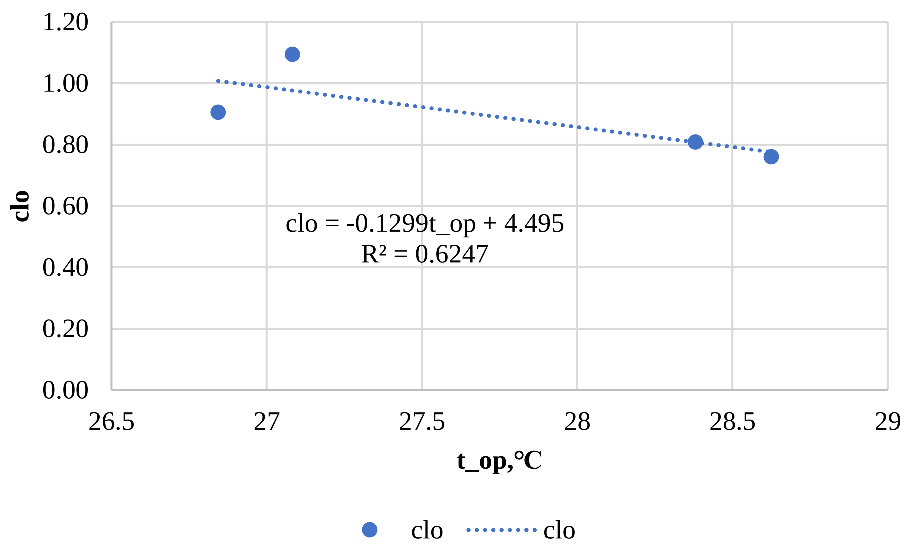

Figure 4.37 Linear regression between clothing insulation and operative temperature.

This research presented a similar result as Cao[67] which people changed clothes to adjust the thermal sensation. According to his thesis, clothing insulation had a negative relation with the operative temperature. Fisher[68] concluded that there was a significant linear relationship between clothing and outdoor temperature by following the clothing habits of 26 people in an office building in the UK. However , Baker[69] insisted that people thought what to wear based on the weather in the morning. In this research, the value of subjective thermal sensation would drop with the increase of clothing insulation; the value of objective thermal sensation would increase with the increase of clothing insulation (shown in Figure 4.38). This research indicated that occupants would wear less clothes to adjust their thermal comfort in maternity hospital.

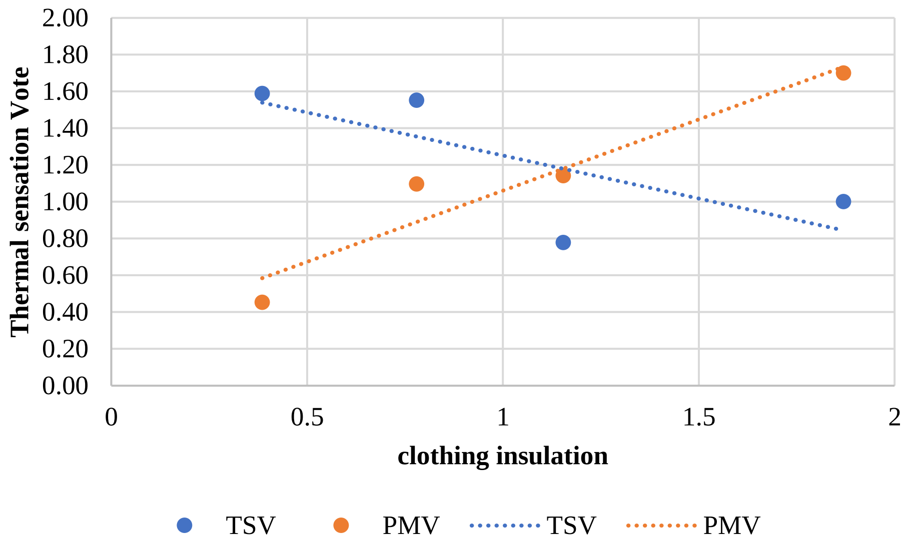

Figure 4.38 Linear regression between clothing insulation and thermal comfort.

4.2.1.4. Velocity of air

In this section, there are two figures to present the relationship between the air velocity and PMV/TSV; the relationship between the operative temperature and the air velocity. The air velocity of all samples was grouped at intervals of 0.01m/s; the average value of each group was taken as an independent variable; the TSV and the PMV values within 0.01m/s bin was averaged as a dependent variable. Figure 4.39 shows the linear regression between the TSV, PMV and the air velocity. Figure 4.40 shows the average air velocity within 0.5℃ operative temperature bins.

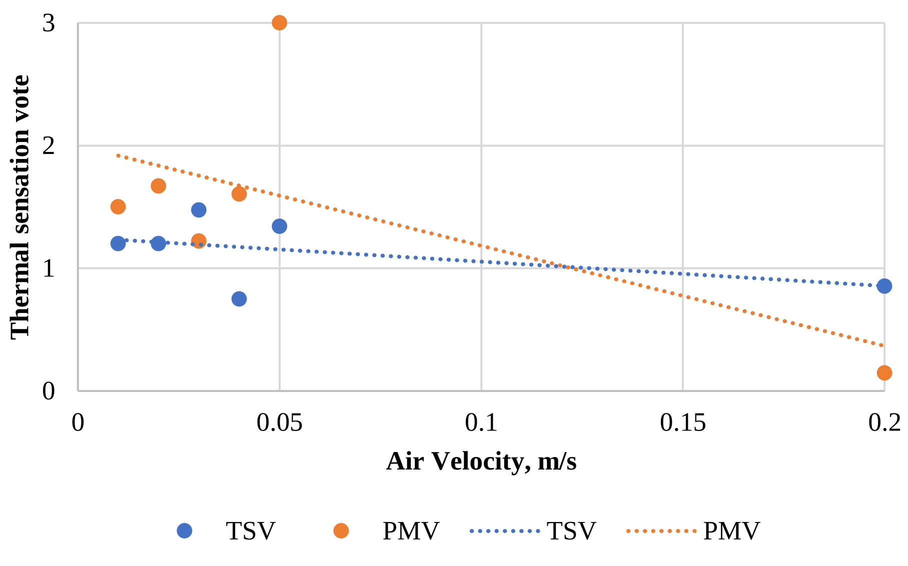

Figure 4.39 Correlation between Air Velocity and TSV, PMV.

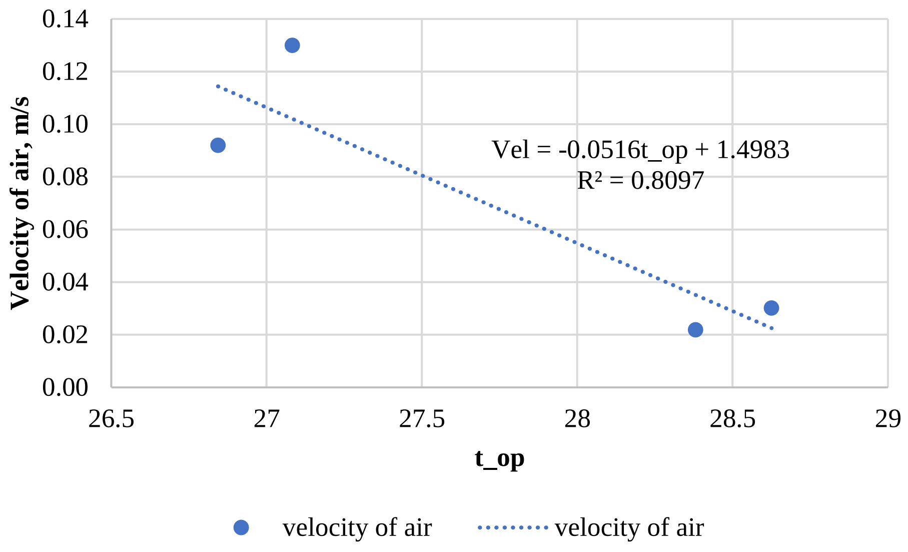

Figure 4.40 Correlation between operative temperature and air velocity.

As shown in Figure 4.39 and Figure 4.40, the change of air velocity was small in observing period. The TSV remained stable with the increase of air velocity in the maternity hospital. But it is worthy to mention that the air velocity dropped with the increase of operative temperature. As mentioned in Cao's[67] research, the air velocity usually decreased with the increase of operative temperature, which indicated that the individual preferred to increase the air velocity to adjust thermal comfort.

Compared to personal behavior, it is easier to control ventilation system to enhance thermal comfort. The hospital is served by central heating system, which cannot be controlled according to personal requirements; the humidifiers are needed to improve the relative humidity; clothing and activity vary from people to people. Therefore, ventilation system would be applied to improve indoor climate.

This hospital is operated by natural ventilation system, which the occupants can change the air velocity by opening windows according their sensation. Due to the influence of China's inherent conception of the confinement, people do not expect to get cold during the period of the delivery. Therefore, they do not choose to open the window or only half-open the window or other way close to air velocity. As shown in Figure 4.41, only 19.64% of the participants would open the window when they were in hospital. As shown in figure 4.42, more than 45.2% of participants wanted to strengthen the air velocity. Therefore, for the sake of increasing the thermal comfort for the occupants by improving air velocity in buildings was also needed to be considered.

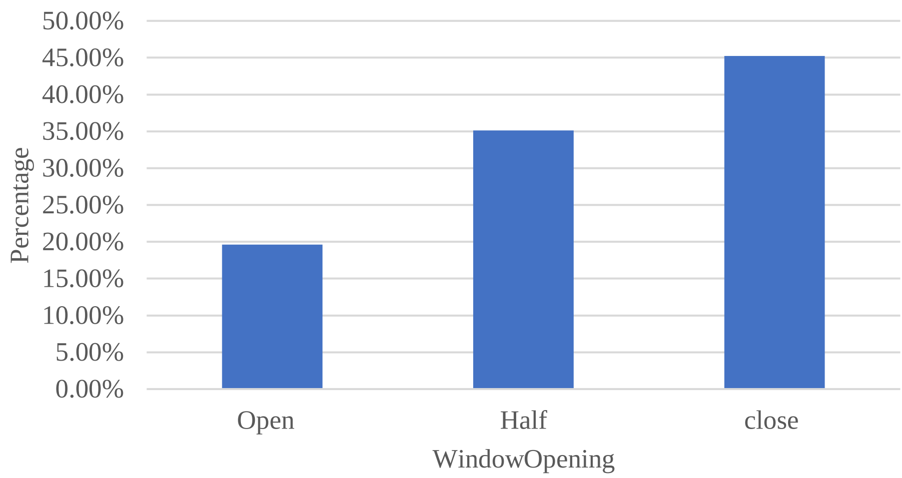

Figure 4.41 Window opening behavior.

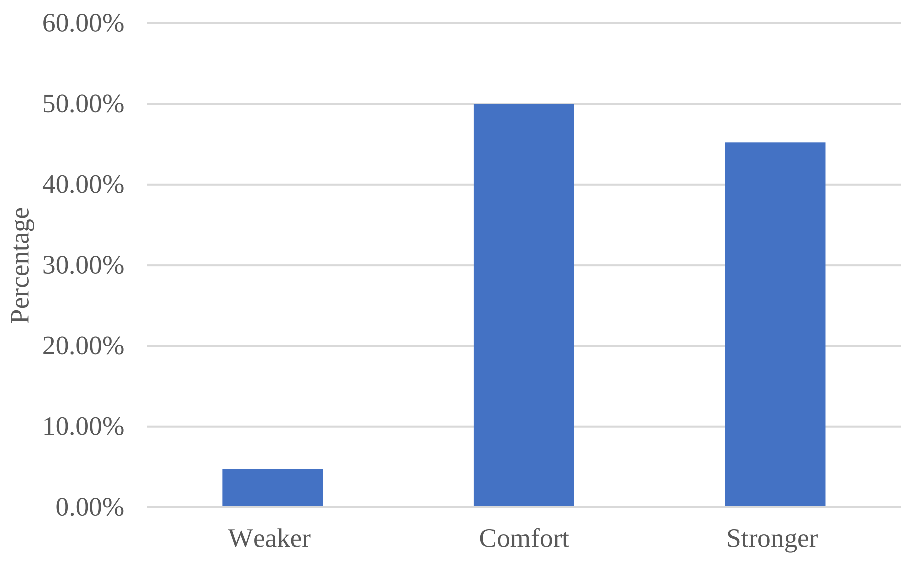

Figure 4.42 The expectation of air velocity.

4.2.1.5. Relative Humidity

The methodology to draw the linear regression line a) between the operative temperature and the relative humidity b) between the linear regression line between the relative humidity and the TSV and the PMV is similar to the air velocity section. The results are shown in Figure 4.43 and Figure 4.44. There was a negative relation between the operative temperature and the relative humidity, which the relative humidity would drop as the increase of the operative temperature. Figure 4.44 demonstrates that subjectives would rate higher thermal sensation with the increase of relative humidity. Thus, individuals felt warmer when they were engaged in a wetter enviroment.

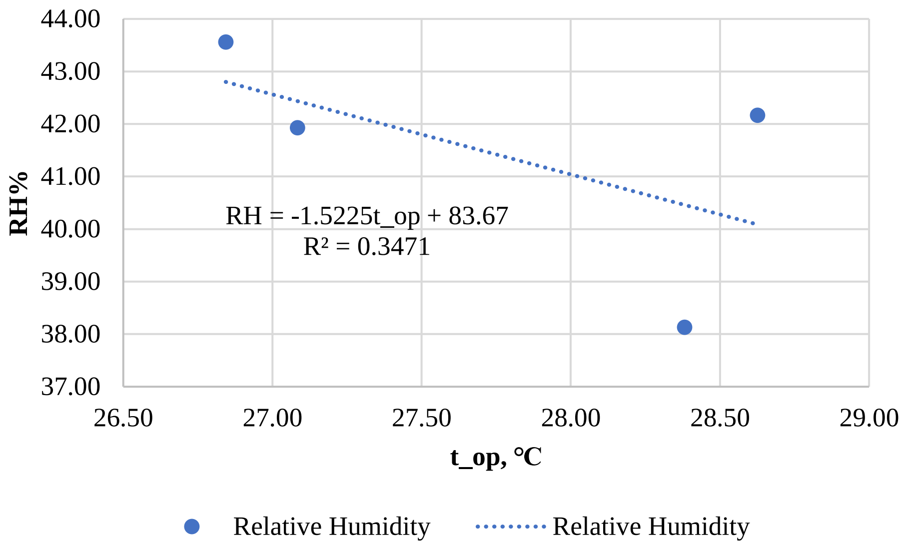

Figure 4.43 Correlation between operative temperature and relative temperature.

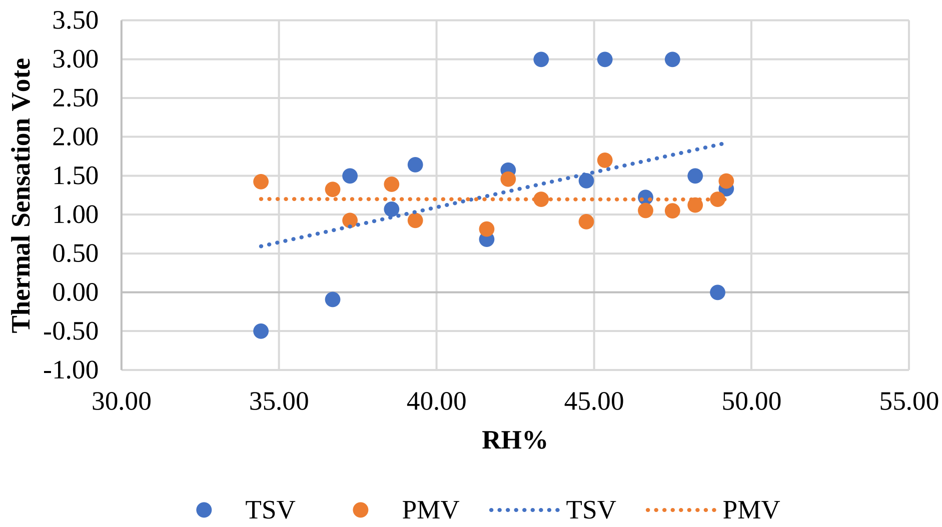

Figure 4.44 Correlation between relative temperature and TSV, PMV.

4.2.1.6. Thermal adaption

There are three methods to evaluate whether the hospital is comfortable or not. As shown in Figure 4.45, it presents the percentage of "do not change" and "want to change" at different operative temperature bins within 0.5°C operative temperature. People who were satisfied with the environment were not willing to change the temperature, therefore they voted “do not change”; people who are not satisfied with the environment would choose “want to warmer” or “want to colder”.

-1,0,1 of the ASHRAE thermal sensation scale illustrate their satisfaction to the environments. Figure 4.46 shows the percentage of satisfaction and dissatisfaction according to the ASHRAE. At the interval of 0.5℃ operate temperature, the all voting of “very comfortable” “comfortable” formed the group of “comfortable”; all voting of “not comfortable” and “cannot tolerate” formed the group of “uncomfortable”.

The percentage of comfort, discomfort and neutral of each operative temperature interval by collecting through the questionnaire are shown in Figure 4.47.

In addition, the average value of each operative temperature bin would represent the group in this research.

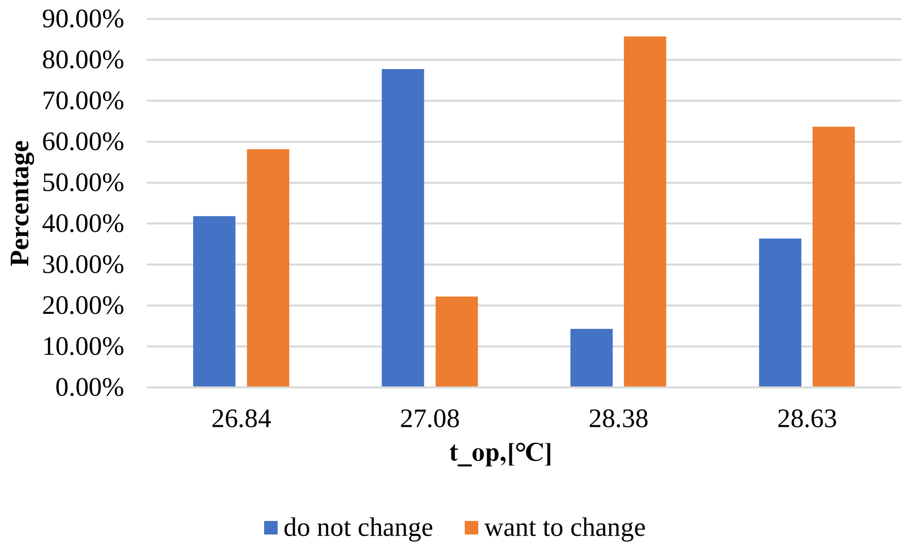

Figure 4.45 Participants' expectation of temperature in hospital.

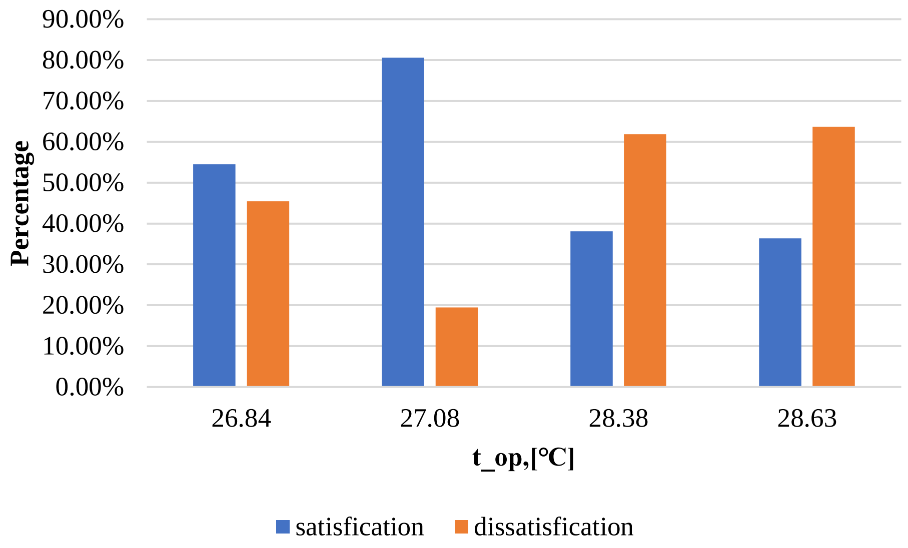

Figure 4.46 Participants' satisfaction of hospital.

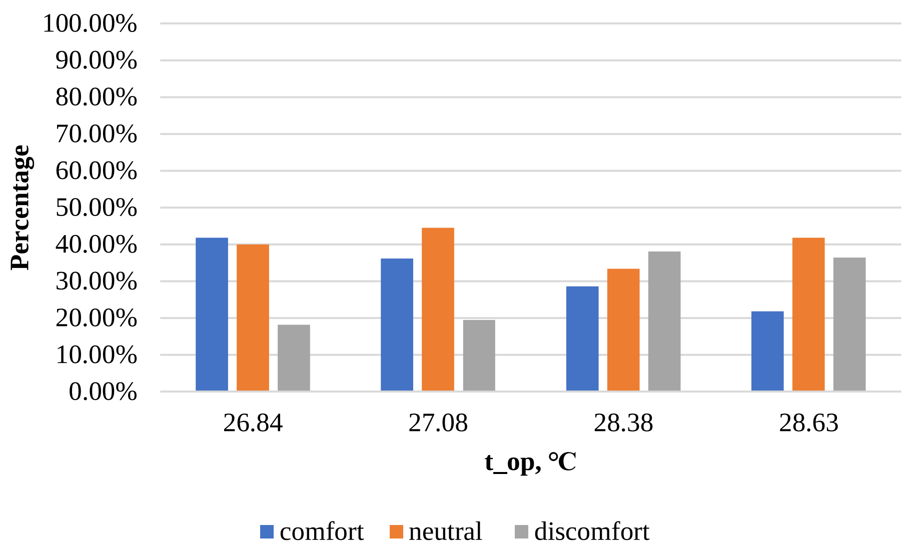

Figure 4.47 Participants' thermal satisfaction of hospital comfort.

Comparisons of temperature preference and 3 points of ASHRAE show that even people perceived comfort to the environment, they were still willing to change the indoor temperature no matter to change the indoor climate to be higher or lower, they just wanted to change. The comparison also indicates that the subjective thermal sensation of the individual was still satisfactory, even though the individual expects the temperature change very much. This indicates that individuals had accepted the hospital environment through their own psychological adjustment. As shown in Figure 4.47, if respondents were asked to answer whether the environment was comfortable or not, the percentage of respondents who voted comfortable decreased with the increase of operative temperature. The results indicate that they preferred the environment with a lower temperature.

According to ASHRAE standard [30], when the thermal acceptability rate is

85%, the indoor environment is comfortable, neutral and acceptable. These three figures are pointed out that even if the hospital environment has reached the domestic standards to keep the hospital operating in an appropriate climate, but the individuals still thought that the hospital environment did not meet their requirements.

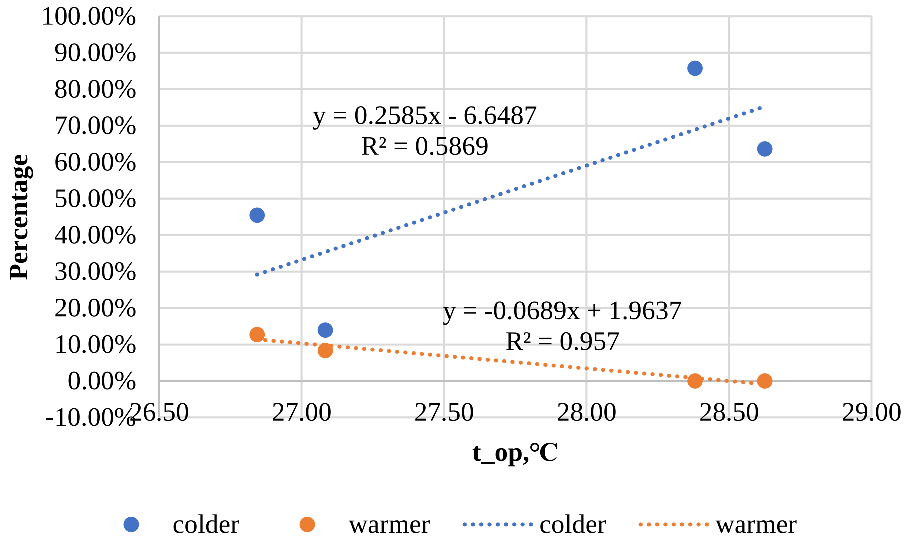

Figure 4.48 Preferred operative temperature.

It demonstrates the probit model of percentage of expecting colder derived from subjective voting of “colder” were plotted against the binned operative temperature. The percentage of expecting warmer was plotted against the binned operative temperature as the same as the colder line. The intersection of two fitting lines was the preferred temperature which is 26.13℃ shown in Figure 4.48.

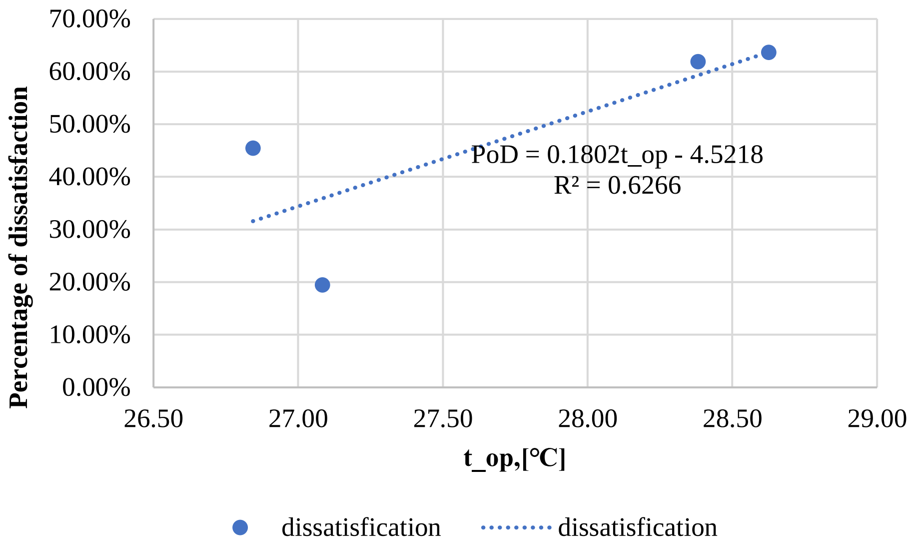

Figure 4.49 Percentage of dissatisfaction.

It indicates that when people rate their thermal sensation as -3,-2,2 or 3, they are dissatisfied with the thermal environment. The probit model of percentage of dissatisfaction derived from subjective voting of " -3,-2,2,3" were plotted against the binned operative temperature.

As shown in Figure 4.49, the percentage of dissatisfaction rose with the increase of operative temperature. When the rate of dissatisfaction is lower than 20%, the temperature will be accepted. Meanwhile, the dissatisfaction rate cannot be negative. Thus, the acceptable temperature for occupants is 25.09-26.2 ℃.

Regression equation of subjective thermal sensation and indoor operating temperature can be used to calculate the 85% acceptable operative range as well. When TSV=±0.85， the upper temperature limit and the lower temperature limit can be calculated and they were 27.54 ℃ and 26.03 ℃ respectively in this study.

The subjective temperature range was 26.03 – 27.54℃. In the same way, the objective acceptable temperature range was 19.41- 26.87℃, which was wider than the subjective range.

4.3.2. Evaluating humidity sensation based on the overall data

Questionnaire also involves the sensibility of humidity which imitated the evaluation of thermal comfort. Participants used 7-point scale to rate their humidity sensation. The definition of 7-point scale is shown on Table 4.8.

Table 4.8 The definition of 7-point humidity scale.

Sensation vote	Description
1	Very wet
2	Wet
3	Slightly wet
4	Neutral
5	Slightly dry
6	Dry
7	Very dry

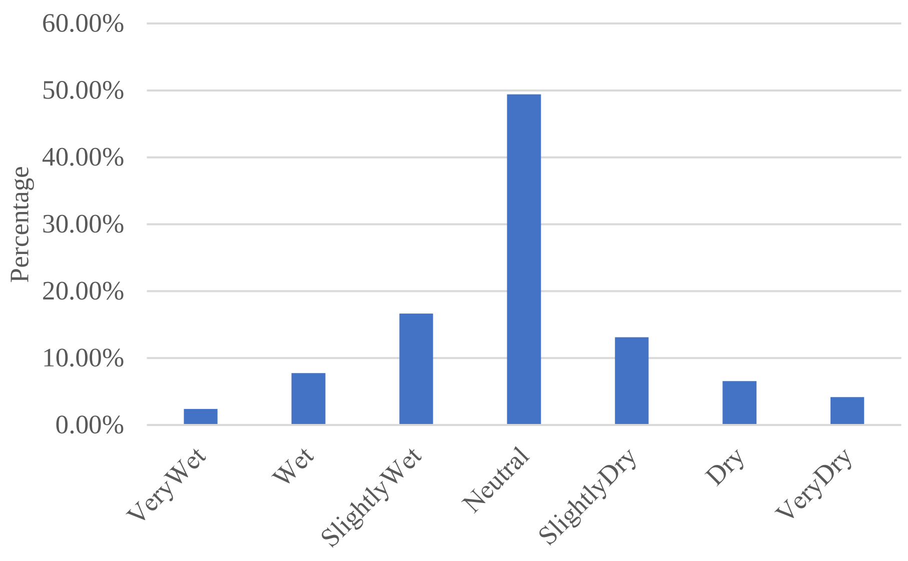

Figure 4.50 The distribution of sense of relative humidity.

Figure 4.50 shows the distribution of sense of relative humidity. It was about 79.1% of people who perceived neutral, which indicated that the humidity condition of the hospital was good and met the requirement of 80% of people. The probit model of the average of relative humidity of each bin against the binned operative temperature is shown in Figure 4.51.

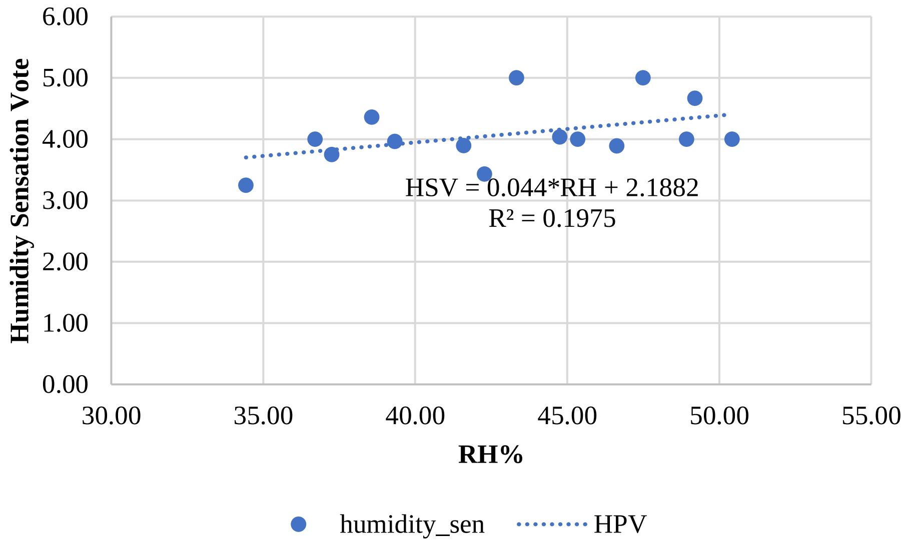

Figure 4.51 Correlation between relative humidity and sense of humidity.

The regression formula of relative humidity and humidity sensation can be obtained:

$$HSV=0.044*RH+2.1882 \quad (4.2)$$

Where:

HSV: is humidity sensation vote.

When individuals neither feel dry or wet at this humidity, HPV=4. When HPV=4, the neutral relative humidity was 41.18%.

The algorithm of expected humidity adopts the method of probability statistics. Figure 4.52 demonstrates the probit model of percentage of getting wetter and getting drier derived from subjective voting of “expectation of getting wetter” and “expectation of getting drier” were drawn against binned relative humidity. The interaction of two lines was the preferred relative humidity, which was 44.63%. Compared to the neutral relative humidity value, the value of expected relative humidity was higher. Though as shown in section 4.3.1.5, people felt much warmer with the increase of relative humidity, people still preferred wetter relative humidity condition.

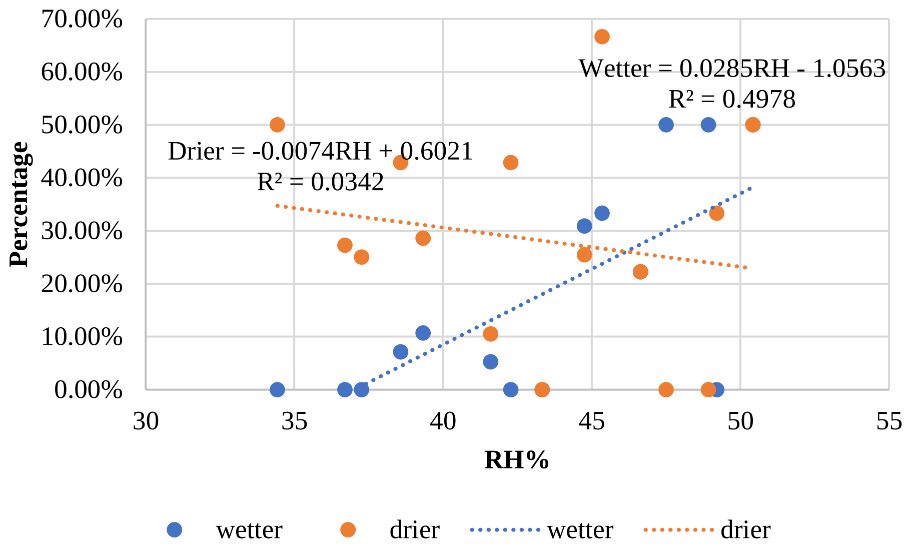

Figure 4.52 Preferred relative humidity.

Imitating the method for calculating the acceptable temperature range, the acceptable relative humidity range can be calculated as well. The linear regression equations are shown in Figure 4.52, which indicated the relationship between the relative humidity and the percentage of people who expected the wetter/direr environments. When sensibility of humidity is 4±0.85, the 80% acceptable range can be observed. The acceptable relative humidity range was 21.86-60.50%. In maternity hospital, people preferred a wetter environment. Though the humidity environment was slightly drier, the occupants can tolerate the dry climate by psychological adaption. The research still recommend that the humidity climate should be above 40%RH.

4.4. Divergence in thermal sensation vote

As mentioned in Section, it just evaluated the personal parameters and environment factors related to PMV model. In this section, some latent variable will be applied to observe the variance in terms of thermal comfort. these parameters includes month, identity, window-opening behavior, the number of surrounding people and room types. ANOVA and t-test were applied to compare the differences in thermal sensation vote.

4.4.1. Months

As shown in Table 4.9, there were significant differences between heating month (in March) and ventilation month (in April) ($p<0.01$) both in TSV and PMV by using t-test analysis. The TSV value in March was obviously lower than in April, which indicated that people perceived warmer in ventilation month though the room was as warm as the heating month. Outdoor temperature in April was higher than it in March, thus, people would gradually adapt warmer outdoor environments. If the outdoor temperature was high, they could feel a bit warmer in the same indoor environment as the low outdoor temperature.

Table 4.9 Different months.

		Sample size	Mean±Std.	Difference between March and April
PMV	**March**	41	0.85±0.58	Significant (p=0.02)
	April	127	1.11±0.71	
TSV	**March**	41	0.15±1.17	Significant (P=0.00)
	April	127	1.62±1.43	

4.4.2. Identities

The results shown on Table 4.10 indicates that it was insignificant ($p<0.05$) when comparing TSV among pregnant woman, staff and visitor. Different people occupying in maternity hospital may feel slightly warm, especially for the pregnant women. However, the objective values of different identities show that pregnant women, visitors and staff may feel differently in the same environment, the objective sensation value of staff was higher than the visitors and the pregnant women follows by. Thus, this research recommend that all people should be taken into account as a whole in the construction of maternal hospitals when it talks about creating a good environment for them.

Table 4.10 Different identities.

		Sample size	Mean±Std.	Difference
PMV	**Pregnant women**	68	0.82±0.84	significant （p=0.01）
	Visitors	83	1.17±0.50	
	Staff	17	1.38±0.49	
TSV	**Pregnant women**	68	1.32±1.45	Not significant （p=0.546）
	Visitors	83	1.29±1.54	
	Staff	17	0.88±1.58	

4.4.3. Window-opening behavior

33 participants opened their windows when they were filling in the questionnaire; 39 participants had half-window-opening behavior; 76 participants did not open the window when they were completing the questionnaire. In order to test whether the window-opening behavior influenced the objective and subjective thermal sensation, this research compared the mean thermal sensation vote values in three groups. There was no significant difference in TSV ($p>0.05$)

shown on Table 4.11; there was a difference in terms of PMV. Therefore, window-opening may not influence individual's subjective thermal comfort at all.

Table 4.11 Different window-opening conditions.

		Sample size	Mean±Std.	Difference
PMV	**Open**	33	1.25±0.60	significant （p=0.000）
	Half	59	1.25±0.65	
	Do not open	76	0.81±0.68	
TSV	**Open**	33	1.30±1.70	Not significant （p=0.978）
	Half	59	1.27±1.52	
	Do not open	76	1.23±1.42	

4.4.4. Room types

The result of homogeneity of variance is homogeneity. After that, Brown-Forsythe variance test was adopted, and the results obtained were presented in Table 4.12. The p-values of the subjective and objective thermal comfort of different types of rooms were all greater than 0.05, indicating that the subjective and objective thermal comfort in single, double, triple and other types of wards were basically the same.

Table 4.12 Different types of room.

		Sample size	Mean±Std.	Difference
PMV	**Single**	8	1.24±0.73	Not significant
	Double	58	1.03±0.63	(p=0.739)
	Triple	69	1.09±0.63	
	Else	33	0.96±0.87	

TSV	**Single**	8	1.00±1.41	Not significant
	Double	58	1.26±1.47	(p=0.942)
	Triple	69	1.25±1.46	
	Else	33	1.36±1.73	

4.4.5. Number of surrounding people

In addition, as shown on Table 4.13, testing as mentioned in Section 4.3.2.4, the number of surrounding people did not affect the subjective and objective thermal comfort of respondents. Participants all perceived slightly warm.

Table 4.13 Different number of surrounding people.

		Sample size	Mean±STD	Difference
PMV	**1**	4	1.53±0.10	Not significant
	2	26	1.05±0.77	(p=0.131)
	3	39	1.06±0.66	
	4	43	0.87±0.79	
	5 and more	56	1.14±0.57	
TSV	**1**	4	1.25±1.50	Not significant
	2	26	1.31±1.37	(p=0.368)
	3	39	1.00±1.36	
	4	43	1.07±1.58	
	5 and more	56	1.57±1.59	

Chapter 5 Conclusions

The following conclusion can be summarized by combining questionnaire delivery and environment measurement together:

- The indoor environment of maternity hospital remained stable. In winter-spring transition season, the air temperature met the requirement. In heating season, it was slightly dry in hospital; in natural ventilation season, the indoor relative humidity was comfortable. However, the air velocity was very low and the value of the concentration of carbon dioxide was high. This research advises that it is necessary to install ventilation system to improve the air quality in maternity hospital.

- This research focuses on thermal comfort in hospital. The results indicated that the habitants inside hospital prefer cooler environment climate. People wear less clothes and increased activity levels to make them comfort with the increase of operative temperature. However, they do not prefer to increase air velocity to adjust their thermal condition.

- The subjective and the objective neutral operative temperature in this hospital was 25.46℃ and 23.77℃ respectively.

  The subjective and the objective acceptable operative temperature range was 19.41℃~26.87℃ and 26.03℃~27.54℃ respectively.

- PMV model was a well predictor to estimate thermal sensation which had no difference between TSV. Results still revealed that objective thermal sensation was a bit cooler than actual thermal sensation.

- In this paper, it can be observed that TSV only varies only in different months; However, PMV value varied from different months, different window opening modes and identities. In maternity hospital, people should be considered together when discussing on the thermal sensation.

- Humidity sensation is another parameter to evaluate the thermal environment. The range of acceptable relative humidity was 21.86-60.50% and the hospital met the requirement. People preferred wetter environments.

Chapter 6 Limitation

In general, this research is very scientific, but there are some limitations in this research.

- Comparing to the previous researches, the number of occupants was quite small. Only 168 effective questionnaires were included in this research.
- This research focus on winter-spring transition season, it is a bit weak to clarify the operation conditions for the hospital. There are two different operation modes in winter and summer.
- This research was conducted in Beijing and the climate of Beijing is temperate and monsoonal climate. However, the climate of China is complex. Thus, the researches should be conducted in different areas to standardize the design of hospital.
- Due to the privacy issue, this research did not contain age, physical information. This information may value in domestic research.
- Besides, the number of operative temperature intervals was only four, which also needed to increase when measure the environmental parameters.
- Focus group was not involved in this research. Focus group can provide a deeper understanding of participants.

Chapter 7 Future work

To make the investigation more comprehensive, this research recommends:

- From the perspective of data collection, there are three suggestions for future research, which are based on the limitations of this study.
    - Though the environment in hospital is basically stable, it is still necessary to record the environmental data while participants are filling the questionnaires due that each ward still slightly varies from another. The researchers should spend more time in hospital in order to get familiar the environment and know how to work with patients.
    - The practicability of study should be considered before the research. This research only focused on the in-patient department of maternity hospital, but there are still functional rooms in hospital. In the future, different departments should be involved together.
    - Focus group should be involved in the future for collecting information on personal requirements. Questionnaire is a just small part to collect patients demand for hospital. If researchers can talk with them and know how they perceive indoor climate, this will help to analyze how patients adapt to hospital environment.
    - Compare to pregnant women, patients are fragile and they are usually lying on bed. This research ignored the influence of the

bedding system which also affects the clothing insulation. For the further study, it should be considered as well.

  - In addition, this research just propose the possibility of ventilation system to enhance thermal comfort in hospital. In the future, CFD model can be used to prove this assumption.

- From the perspective of different identities
  - It is difficult to study on new-born babies, for they just cry to express their feelings. Hospital is the first place for them to touch the world; it will be better if they are surrounded by comfortable environment for themselves not just engaged in the previous environment. But it is a bit difficult to measure the thermal sensation of new-born babies.

Reference

1. China, N.B.o.S.o.t.P.s.R.o., *China Statistical Year Book 2017*, ed. Z.Y. Zhihong Xing. 2017, Beijing, China: Chinese Statistics Press
2. MARC SCHWEITZER, M.A., 1 LAURA GILPIN, M.F.A., R.N.,2 and SUSAN FRAMPTON, Ph.D.3, *Healing Spaces: Elements of Environmental Design.* The journal of Alternative and Complementary Medicine, 2004. **10**(Supplement 1): p. S-71–S-83.
3. YAO, Y., B. LIU, and G.-e. LIU, *The Relationship between Maternal and Child Health Care Institution Scale and Maternal-Child Health Care Level———An Empirical Analysis Based on Province level Panel Data.* POPULATION ＆ DEVELOPMENT, 2014. **20**(4): p. 65-75.
4. Chen, X., *THE EMPHASIS OF MATERNAL AND CHILD HEALTH HOSPITAL DESIGN.* Chinese Hospital Architecture & Equipment, 2012. **04**: p. 25-27.
5. Yau, Y.H. and B.T. Chew, *Thermal comfort study of hospital workers in Malaysia.* Indoor Air, 2009. **19**(6): p. 500-10.
6. Olesen, B.W., *International standards and the ergonomics of the thermal environment.* Appkd Ergonomics, 1995. **26**(4): p. 293-302.
7. Wu, X., *Problems in HVAC design for large general hospital buildings.* Journal of HV&AC 2009. **39**(4): p. 5-8.
8. Zhang, H., N. Gong, and L. Zhao, *Indirect effects of air-conditioning relative humidity of hospital buildings in summer on human health.* Journal of Central South University (Science and Technology), 2012. **43**(9): p. 3727-3733.
9. Verheyen, J., et al., *Thermal comfort of patients: Objective and subjective measurements in patient rooms of a Belgian healthcare facility.* Building and Environment, 2011. **46**(5): p. 1195-1204.
10. Hwang, R.-L., et al., *Patient thermal comfort requirement for hospital environments in Taiwan.* Building and Environment, 2007. **42**(8): p. 2980-2987.
11. Pourshaghaghy, A. and M. Omidvari, *Examination of thermal comfort in a hospital using PMV-PPD model.* Appl Ergon, 2012. **43**(6): p. 1089-95.
12. Wang, Z., *A field study of the thermal comfort in residential buildings in Harbin.* Building and Environment, 2006. **41**(8): p. 1034-1039.
13. Skoog, J., N. Fransson, and L. Jagemar, *Thermal environment in Swedish hospitals.* Energy and Buildings, 2005. **37**(8): p. 872-877.
14. Sattayakorn, S., M. Ichinose, and R. Sasaki, *Clarifying thermal comfort of healthcare occupants in tropical region: A case of indoor environment in Thai hospitals.* Energy and Buildings, 2017. **149**: p. 45-57.
15. Del Ferraro, S., et al., *A field study on thermal comfort in an Italian hospital considering differences in gender and age.* Appl Ergon, 2015. **50**: p. 177-84.
16. Arundel, A.V., et al., *Indirect Health Effects of Relative Humidity in Indoor*

Environments. Environmental Health Perspectives, 1986. **65**: p. 351-361.
17. Hashiguchi, N., et al., *Effects of setting up of humidifiers on thermal conditions and subjective responses of patients and staff in a hospital during winter.* Appl Ergon, 2008. **39**(2): p. 158-65.
18. Qi, H. and H. Zhang, *Humid Comfort Demands Analysis of Air-conditioning Environment in Chongqing Hospital.* Refrigeration and Air Conditioning, 2013. **27**(4): p. 415-419.
19. Yu, J. and H. Zhang, *Thermal Comfort of The Patients and Its Influence about Evaluating of Thermal Environment.* Refrigeration and Air Conditioning, 2015. **29**(5): p. 505-508.
20. Ireton-Jones, C., et al., *Equations for the Estimation of Energy Expenditures in Patients with Burns with Special Reference to Ventilatory Status*. Vol. 13. 1992. 330-3.
21. Gong, N., *The Impacts of Indoor Thermal Parameters on Human Comfort and Health in Hospital Buildings* in *College of faculty of Urban Construction and Environmental Engineering*. 2011, Chongqing University: Chongqing, China p. 92.
22. Gong, N. and HualingZhang, *Thermal and Humid Comfort Requirement in Hospital Environment in Winter.* Refrigeration and Air Conditioning, 2012. **26**(4): p. 430-435.
23. Feng, H., *Study on the Thermal Comfort in Hospital Wards*, in *Faculty of Urban Construction and Environmental Engineering* 2015, Chongqing University: Chongqing, China
24. FANGER, P.O., *Assessment of man's thermal comfort in practice.* Industrial Medicine, 1973. **30**: p. 313-324.
25. Fanger, P.O., *Thermal comfort. Analysis and applications in environmental engineering*. 1970: Copenhagen: Danish Technical Press. 244 pp.
26. Gallardo, A., et al., *Evaluating Thermal Comfort in a Naturally Conditioned Office in a Temperate Climate Zone.* Buildings, 2016. **6**(3).
27. Oseland, N.A., *Predicted and reported thermal sensation in climate chambers, offices and homes.* Energy & Buildings, 1995. **23**(2): p. 105-115.
28. Nastase, I., C. Croitoru, and C. Lungu, *A Questioning of the Thermal Sensation Vote Index Based on Questionnaire Survey for Real Working Environments.* Energy Procedia, 2016. **85**(C): p. 366-374.
29. ISO7730, *Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteri*. 2005, International Organization for Standardization
30. ASHRAE Technical Committees, T.G., AND TECHNICAL RESOURCE GROUPS, *ASHRAE-2013 ASHRAE Handbook*. 2013.
31. Dear, R.d., G. BragerÁ, and D. CooperÀ, *Developing an adaptive model of thermal comfort and preference.* ASHRAE RP- 884, 1997.
32. Humphreys, M.A., J.F. Nicol, and I.A. Raja, *Field Studies of Indoor Thermal Comfort and the Progress of the Adaptive Approach.* Advances in Building

Energy Research, 2007. **1**(1): p. 55-88.
33. Dear, R.J.d., et al., *Developing an adaptive model of thermal comfort and preference / Discussion.* ASHRAE Transactions, 1998. **104**(145): p. 145-167.
34. Zhao, R., *Discussion on thermal comfort.* HV&AC, 2000. **30**(3): p. 25-26.
35. Gagge, A.P., *Introduction to thermal comfort.* INSERM, 1977.
36. Hensel, H. and K. Schafer, *Thermoreception and Temperature Regulation in Man*, in *Recent Advances in Medical Thermology*, E.F.J. Ring and B. Phillips, Editors. 1984, Springer New York: Boston, MA. p. 51-64.
37. Chatonnet, J. and M. Cabanac, *The perception of thermal comfort.* International Journal of Biometeorology, 1965. **9**(2): p. 183-193.
38. Zhu, Y., *Built Environment*, ed. Q. Qi. 2010, Beijing China Architecture & Building Press.
39. Cao, B., *Human thermal adaptation in real building environment(1)---camparison between air-conditioned and non-air-conditioned public buildings* Journal of HV&AC, 2014. **44**(8): p. 74-79.
40. Cao, B., et al., *Individual and district heating: A comparison of residential heating modes with an analysis of adaptive thermal comfort.* Energy and Buildings, 2014. **78**: p. 17-24.
41. Fanger, P.O., J. Højbjerre, and J.O.B. Thomsen, *Can winter swimming cause people to prefer lower room temperatures?* International Journal of Biometeorology, 1977. **21**(1): p. 44-50.
42. Fanger, P.O., N.O. Breum, and E. Jerking, *Can Colour and Noise Influence Man's Thermal Comfort?* Ergonomics, 1977. **20**(1): p. 11-18.
43. Bulcaoa, C.F., et al., *Relative contribution of core and skin temperatures to thermal comfort in humans.* Journal of Thermal Biology, 2000. **25**: p. 147-150.
44. Liu, W., Z. Lian, and Y. Liu, *Heart rate variability at different thermal comfort levels.* Eur J Appl Physiol, 2008. **103**(3): p. 361-6.
45. WU, G. and W. ZHANG, *Neural mechanism of EEG wave.* Journal of Clinical Electroencephalology (China), 2000. **9**(3): p. 188-190.
46. Kanosuea, K., et al., *Brain activation during whole body cooling in humans studied with functional magnetic resonance imaging.* Neuroscience Letters 2002. **329**(2): p. 157–160.
47. Mohra, E., J. Langbeinb, and G. Nu¨rnbergc, *Heart rate variability--A noninvasive approach to measure stress in calves and cows.* Physiology & Behavior 2002. **75**(1/2): p. 251–259.
48. QIU, M., et al., *STUDY ON THE SWEAT REGULATION MECHANISM UNDER DIFFERENT TEMPERATURE CIRCUMSTANCE AND DIFFRENT INTENSIVE EXERCISE.* Chinese Journal of Applied Physiology, 2005. **21**(1): p. 90-94.
49. BEDFORD, T., *Environmental Warmth and Human Comfort.* British Journal of Applied Physics, 1950. **1**(2): p. 33-38.
50. Zhou, X., et al., *Experimental study of the influence of anticipated control on human thermal sensation and thermal comfort.* Indoor Air, 2014. **24**(2): p. 171-7.

51. Ho, S.H., L. Rosario, and M.M. Rahman, *Three-dimensional analysis for hospital operating room thermal comfort and contaminant removal.* Applied Thermal Engineering, 2009. **29**(10): p. 2080-2092.
52. FANGER, P.O., *Indoor Air Quality in the 21st Century: Search for Excellence.* INDOOR AIR, 2001. **10**(2): p. 68-73.
53. GB51039-2014, *Code for design of general hospital* 2014, Ministry of housing and Urban-Rural Development of the People's Republic of China: Beijing, China.
54. JGJ49-88, *General Hospital of building design (TS)*. 1988, Ministry of construction of the People's Republic of China and Ministry of Health of the People's Republic of China Beijing, China.
55. ISO7726:1998(E), *Ergonomics of the thermal environment — Instruments for measuring physical quantities*. 1998, International Organization for Standardization
56. Cao, B., *Indoor thermal environment and human thermal adaptation in residential building in various climate zones during winter* Journal of Tsinghua University (Science and Techology), 2012. **52**(4): p. 499-503.
57. De Giuli, V., et al., *Measured and perceived indoor environmental quality: Padua Hospital case study.* Building and Environment, 2013. **59**: p. 211-226.
58. Standardization, t.I.O.f., *ISO 7730*. 2005.
59. Dear, R.J.d. and M.E. Fountai, *Field experiments on occupant comfort and office thermal environments in a hot-humid climate.* ASHRAE Transactions, 1994. **100**(2): p. 457-475.
60. JGJ26-2010, *Design standard for energy efficiency of residential buildings in severe cold and cold zones* 2010, Ministry of housing and Urban-Rural Development of the People's Republic of China: Beijing,China.
61. DB11687-2015, *Design Standard for Energy Efficiency Of Public Buildings* 2015, Beijing Municipal Planning Commission: Beijing, China.
62. GBT18883-2002, *Indoor air quality standard* 2002, Ministry of Health of the People's Republic of China and State Administration for Quality Supervision and Inspection and Quarantine (AQSIQ) and State Environmental Protection Administration (SEPA) Beijing,China.
63. GB/T50785-2012, *Evaluation Standard for Indoor Thermal Environment in Civic Buildings* in *Beijing, China*. 2012: Ministry of housing and Urban-Rural Development of the People's Republic of China.
64. Fanger, P.O. and J. Toftum, *Extension of the PMV model to non-air-conditioned building in warm climates.* Energy and Buildings, 2002. **Vol. 34**: p. 533-536.
65. Cao, B., et al., *Field study of human thermal comfort and thermal adaptability during the summer and winter in Beijing.* Energy and Buildings, 2011. **43**(5): p. 1051-1056.
66. Xia, Y., R. Zhao, and Y. Jiang, *Thermal comfort in natural ly venti lated houses in Bei jing.* HV&AC, 1999. **29**(2): p. 1-4.

67. Cao, B., *Research on the Impacts of Climate and Built Environment on Human Thermal Adaptation* in *Civil Engineering* 2012, Tsinghua University Beijing.
68. Fishman, D.S. and S.L. Pimbert, *The thermal environment in offices.* Energy and Buildings, 1982. **5**(2): p. 109-116.
69. Baker, N. and M. Standeven, *Thermal comfort for free-running buildings.* Energy and Buildings 1996. **23** p. 175-182.

Appendix

Table A: questionnaire

北京市医院舒适性调查

Survey for thermal Comfort in maternity hospital

尊敬的受访者，您好！

Dear participants:

感谢您对此项调查的配合！本调查所得信息全部用于医院研究，将为您绝对保密，请您放心。调查问卷包含 17 个问题（共三页）。请您根据您的情况作答。

Thank you for joining this project. The information obtained from this survey only be used for hospital thermal comfort only. This questionnaire contains 17 questions and please answer the questions according to your situation.

1. 您是

who are you

a) 孕妇 pregnant woman

b) 家属 visitor

c) 医院工作人员 staff

2. 您所在的房间

what kind of room do you live in?

a) 单人间 single room

b) 两人间 double room

c) 三人间 triple room

d) 其他 else

3. 填写时间

when do you answer this questionnaire?

a) 上午 morning：________时_______分(am)

b) 下午 afternoon：________时_______分(pm)

4. 您此时的穿衣情况（请将您此时穿着的服装全部勾选出来）

what kind of clothes do you wear?

a) 内衣 underwear

秋衣 pajamas 秋裤 pajamas 保暖秋衣 pajamas 保暖秋裤 pajamas 短袖汗衫 shirt 背心 vest

b) 上装 coat

毛衣（薄）long blouse with long sleeves 毛衣（厚）sweater 针织衫（薄）short blouse with long sleeves 针织衫（厚）long blouse with long sleeves 羊绒衫 sweater 毛背心 vest 长袖衬衫/T 恤 long blouse with long sleeves 连衣裙 one piece dress

c) 外衣 outerwear

羊毛上衣（长）/羽绒服/棉服（长）/冲锋衣 down jacket 羽绒背心 jacket 棉服（短）/西服上衣/夹克/羊毛上衣（短）/风衣（薄）jacket 运动休闲外套 sports coat 睡衣（薄）pajamas(slight) 睡衣（厚）pajamas(thick)风衣（厚）dust coat

d) 下装 trousers

西裤/牛仔裤 normal trousers 打底裤（薄）&打底裤（厚） light trousers 睡裤（薄）long johns slight(= half clo of thick) 睡裤（厚）long johns thick 内加绒外裤&棉裤&羊绒裤 padded trousers 短裤 shorts 半裙 skirts(clo=shorts)

e) 袜

未到脚踝的短袜 socks 到踝短袜 short 到膝长袜 long socks

f) 鞋 shoes

皮鞋/运动鞋 sports shoes/leather shoes 凉拖鞋 slippers 棉拖鞋 cotton slippers

g) 其他 Else

5. 您填写本问卷时坐的椅子为

what kind of chair do you sit on when you fill the questionnaire?

a) 无椅子 without chair

b) 木质椅子 wooden chair

c) 标准办公椅 standard office chair

d) 床 bed

6. 您此时所在房间内的人数（包括自己在内）

How many people are surrounding you? (including you)

a) 1 one

b) 2 two

c) 3 three

d) 4 four

e) 5 及以上 five or more

7. 您所在的房间是否开窗

Do you open the window?

a) 开窗 yes

b) 半开窗 half

c) 未开窗 no

8. 您在填写问卷 30 分钟内的活动状态为

what is your activity level within 30 minutes when you fill this questionnaire?

a) 坐姿，放松 sitting, relax

b) 坐姿，轻微活动 sitting, light activity

c) 站立，放松无活动 standing, relax without activity

d) 站立，轻度活动 standing, light activity

e) 平地步行 walking

f) 平躺 lying on the bed

9. 您现在的冷热感觉

Is it cold or hot in hospital?

a) 冷 cold

b) 凉 cool

c) 微凉 slightly cool

d) 适中 neutral

e) 微暖 slightly warm

f) 暖 warm

g) 热 hot

10. 您现在希望医院室内温度

Do you want to get warmer or colder？

a) 凉一些 colder

b) 不变 do not change

c) 暖一些 warmer

11. 您对当前医院室内的湿度，您感觉

Do you think that the air is so dry or wet?

a) 非常潮湿 very wet

b) 潮湿 wet

c) 有点潮湿 slightly wet

d) 适中 neutral

e) 有点干燥 slightly dry

f) 干燥 dry

g) 非常干燥 very dry

12. 您希望医院室内湿度

Do you want to get drier or wetter

a) 潮湿一些 wetter

b) 不变 do not change

c) 干燥一些 drier

13. 对当前医院室内的气流情况，您感觉

What do you think of wind speed?

a) 没有风 no wind

b) 有轻微吹风感 slightly wind

c)　　有明显的的吹风感 clear wind

d)　　有比较强烈的吹风感 strong wind

14.　　您现在希望吹风感

Do you want air speed to get weaker or stronger?

a)　　更弱一些 weaker

b)　　不变 do not change

c)　　更强一些 stronger

15.　　对于当前医院室内环境（综合考虑温度、湿度、吹风感等），您认为其舒适度

What do think of the overall environment? (considering temperature, humidity and air speed)

a)　　非常舒适 very comfort

b)　　一般 comfort

c)　　适中 neutral

d)　　有点儿不能忍受 slightly discomfort

e)　　难以忍受 discomfort

16.　　对于当前医院室内环境（综合考虑温度、湿度、吹风感等），您认为是否可以接受

Is it acceptable for the current environment in hospital?

a)　　完全不可接受 totally unacceptable

b)　　有点不可接受 unacceptable

c)　　刚好可接受 acceptable

d) 完全可接受 totally acceptable

Table B: original data

No	Month	Iden	Room Type	num	WOp	Clothing	Tem_air	Tem_R	Activity	Ven	H	Tem_op	PMV	PPD_pmv	TSV	PPD_tsv	tem_EXP	H_sen	H_exp	ven_sen	ven_exp	comfort	expect	diff
1	4	3	4	5	1	0.74	28.52	28.52	1	0.05	43.33	28.5	1.2	35.2	3	99.12	1	5	2	2	3	4	2	-1.8
2	4	1	3	3	1	0.57	28.72	28.72	1.2	0.03	41.42	28.7	1.3	40.3	3	99.12	1	5	1	1	2	4	2	-1.7
3	4	1	1	2	3	0.41	28.73	28.73	0.7	0.04	46.62	28.7	-0.5	10.2	1	26.12	1	4	2	1	2	1	3	-1.5
4	4	1	2	2	3	0.5	28.73	28.73	0.7	0.04	46.62	28.7	-0.3	6.9	2	76.76	1	5	1	2	2	2	3	-2.3
5	4	3	4	5	2	0.63	28.73	28.73	1.6	0.03	46.62	28.7	1.6	56.3	3	99.12	1	1	3	1	3	4	2	-1.4
6	4	3	3	3	2	0.99	28.73	28.73	1.6	0.03	46.62	28.7	1.8	67	0	5	2	3	2	2	3	2	3	1.8
7	4	2	3	2	2	0.55	28.73	28.73	1	0.03	46.62	28.7	1.1	30.5	0	5	2	4	2	2	2	3	3	1.1
8	4	1	3	3	1	0.43	28.73	28.73	1.6	0.03	46.62	28.7	1.5	50.9	0	5	2	4	2	2	2	3	4	1.5
9	4	1	3	3	3	0.95	28.73	28.73	0.7	0.02	41.8	28.7	0.4	8.3	0	5	2	4	2	1	2	3	3	0.4
10	4	3	4	5	2	0.61	28.73	28.73	1.6	0.03	46.62	28.7	1.6	56.3	2	76.76	1	3	3	1	3	2	3	-0.4
11	4	3	4	5	1	0.82	28.62	28.62	1.6	0.03	38.85	28.6	1.6	56.3	0	5	2	5	2	1	1	3	3	1.6
12	4	2	3	3	1	1.1	28.72	28.72	1.2	0.03	41.42	28.7	1.6	56.3	0	5	2	4	2	2	1	3	3	1.6
13	4	2	2	2	3	1.09	28.62	28.62	1	0.05	38.85	28.6	1.5	50.9	3	99.12	1	5	2	1	3	2	2	-1.5
14	4	1	3	2	2	0.7	28.68	28.68	1	0.02	38.22	28.7	1.2	35.2	0	5	2	3	3	2	2	3	3	1.2
15	4	1	2	3	3	0.98	28.7	28.7	0.7	0.05	39.82	28.7	0.4	8.3	3	99.12	1	2	3	1	3	2	2	-2.6
16	4	2	3	1	3	0.85	28.7	28.7	1.4	0.04	38.12	28.7	1.6	56.3	2	76.76	1	3	3	2	3	2	2	-0.4
17	4	2	2	1	2	0.44	28.73	28.73	1.4	0.03	46.62	28.7	1.4	45.5	0	5	2	4	2	2	2	3	4	1.4
18	4	2	3	3	2	0.57	28.62	28.62	1.4	0.04	38.85	28.6	1.4	45.5	0	5	2	4	2	2	2	3	4	1.4
19	4	2	3	4	1	0.79	28.7	28.7	1.9	0.05	39.82	28.7	1.8	67	3	99.12	1	4	2	1	3	2	3	-1.2
22	4	2	2	4	1	1	28.62	28.62	1	0.04	38.85	28.6	1.5	50.9	3	99.12	1	2	3	2	1	3	3	-1.5
23	4	2	3	5	2	0.98	28.7	28.7	1.4	0.05	39.82	28.7	1.6	56.3	3	99.12	1	2	3	2	3	2	3	-1.4
24	4	2	3	5	2	0.73	28.7	28.7	1.6	0.05	39.82	28.7	1.6	56.3	3	99.12	1	2	3	1	3	3	3	-1.4
25	4	1	2	4	2	0.37	28.7	28.7	1.6	0.04	38.12	28.7	1.4	45.5	0	5	2	4	3	1	2	3	3	1.4
26	4	2	3	5	2	0.52	28.68	28.68	1.4	0.05	38.22	28.7	1.3	40.3	3	99.12	2	4	3	1	2	3	3	-1.7
27	4	1	2	3	2	0.35	28.73	28.73	1.4	0.02	41.8	28.7	1.2	35.2	3	99.12	1	4	2	1	2	3	4	-1.8
28	4	2	2	4	2	0.52	28.62	28.62	1.4	0.04	38.85	28.6	1.3	40.3	3	99.12	1	4	3	1	2	3	3	-1.7
29	4	2	3	3	3	0.59	28.53	28.53	1.4	0.03	37.38	28.5	1.4	45.5	2	76.76	1	3	3	2	3	2	2	-0.6
30	4	1	3	4	3	0.6	28.43	28.43	1.6	0.02	39	28.4	1.5	50.9	2	76.76	1	3	3	2	3	2	3	-0.5
32	4	1	2	2	3	0.82	28.53	28.53	1.6	0.03	44.38	28.5	1.6	56.3	2	76.76	2	4	1	2	3	3	3	-0.4
33	4	3	4	5	3	0.63	28.57	28.57	1.4	0.02	36.67	28.6	1.4	45.5	1	26.12	1	4	3	2	3	3	3	0.4
34	4	3	4	5	1	0.74	28.57	28.57	1.6	0.02	36.67	28.6	1.6	56.3	3	99.12	1	1	2	1	3	4	2	-1.4

35	4	2	3	3	1	1.1	28.43	28.43	1	0.02	39	28.4	1.5	50.9	0	5	1	4	2	1	3	3	2	1.5
36	4	2	3	3	2	1.12	28.53	28.53	1	0.03	37.38	28.5	1.5	50.9	3	99.12	1	5	2	1	3	4	3	-1.5
37	4	1	2	2	1	0.96	28.28	28.28	1.2	0.03	34.43	28.3	1.4	45.5	0	5	2	3	2	1	2	2	3	1.4
38	4	2	3	3	1	1.05	28.53	28.53	1	0.02	44.9	28.5	1.5	50.9	0	5	2	4	2	2	2	2	3	1.5
39	4	2	2	4	1	0.57	28.28	28.28	1.9	0.03	34.43	28.3	1.6	56.3	0	5	1	3	3	2	2	3	3	1.6
40	4	1	3	5	2	0.63	28.28	28.28	1.6	0.03	34.43	28.3	1.4	45.5	0	5	2	4	2	2	2	3	3	1.4
41	4	1	1	1	2	1	28.55	28.55	1.2	0.03	50.42	28.6	1.6	56.3	3	99.12	1	2	3	2	3	4	2	-1.4
42	4	2	1	2	2	1	28.43	28.43	1.2	0.02	39	28.4	1.5	50.9	3	99.12	1	2	3	2	3	5	1	-1.5
43	4	1	2	2	2	1	28.53	28.53	1.2	0.03	44.38	28.5	1.6	56.3	3	99.12	2	3	3	2	3	4	2	-1.4
44	4	2	2	2	2	1.25	28.8	28.8	1.2	0.02	45.35	28.8	1.8	67	3	99.12	1	2	3	2	3	4	2	-1.2
45	4	1	3	2	2	1	28.53	28.53	1.2	0.02	44.9	28.5	1.6	56.3	3	99.12	1	2	3	2	3	4	2	-1.4
46	4	1	2	2	2	1.03	28.53	28.53	1.2	0.03	44.38	28.5	1.6	56.3	3	99.12	1	2	3	2	3	4	2	-1.4
47	4	2	4	5	1	0.74	28.28	28.28	1.2	0.03	34.43	28.3	1.3	40.3	-2	76.76	1	3	3	2	3	2	2	3.3
48	4	2	3	3	2	1.19	28.68	28.68	1.2	0.02	42.43	28.7	1.7	61.8	3	99.12	1	2	3	2	3	4	2	-1.3
49	4	2	2	2	1	0.64	28.53	28.53	1.9	0.02	44.9	28.5	1.8	67	3	99.12	1	7	1	1	3	4	1	-1.2
50	4	1	3	4	1	0.86	28.8	28.8	1.6	0.02	45.35	28.8	1.7	61.8	3	99.12	1	7	1	2	2	4	2	-1.3
51	4	1	2	2	1	0.81	28.55	28.55	1	0.03	50.42	28.6	1.4	45.5	3	99.12	1	6	1	1	3	3	2	-1.6
52	4	2	3	4	2	0.84	28.53	28.53	1	0.03	44.38	28.5	1.3	40.3	3	99.12	1	5	1	1	3	4	2	-1.7
53	4	1	4	3	1	0.97	28.53	28.53	1.4	0.02	44.9	28.5	1.6	56.3	3	99.12	1	7	1	2	3	5	1	-1.4
54	4	3	4	5	2	0.34	28.53	28.53	1.6	0.03	37.38	28.5	1.3	40.3	3	99.12	1	2	3	1	3	4	2	-1.7
55	4	1	2	5	2	0.92	28.68	28.68	1.6	0.02	42.43	28.7	1.7	61.8	3	99.12	1	3	3	1	3	5	1	-1.3
56	4	2	3	5	2	0.7	28.68	28.68	1.2	0.02	42.43	28.7	1.4	45.5	3	99.12	1	3	3	1	3	5	1	-1.6
57	4	1	3	5	2	1	28.8	28.8	1.2	0.02	45.35	28.8	1.6	56.3	3	99.12	1	3	3	1	3	4	2	-1.4
58	4	2	3	5	2	0.7	28.53	28.53	1.6	0.03	44.38	28.5	1.6	56.3	2	76.76	1	3	3	1	3	4	2	-0.4
59	4	1	2	3	2	0.87	28.53	28.53	1.6	0.03	44.38	28.5	1.7	61.8	0	5	2	3	3	2	2	3	3	1.7
60	4	1	1	2	2	0.73	28.53	28.53	1.6	0.02	44.9	28.5	1.6	56.3	0	5	2	4	2	2	2	3	3	1.6
61	4	2	2	3	2	0.45	28.53	28.53	1.9	0.03	37.38	28.5	1.6	56.3	0	5	2	4	2	3	2	3	3	1.6
62	4	3	4	5	1	0.42	28.57	28.57	1.9	0.02	36.67	28.6	1.6	56.3	0	5	2	4	2	2	2	3	3	1.6
63	4	2	3	4	2	0.51	28.57	28.57	1.9	0.02	36.67	28.6	1.6	56.3	0	5	2	4	2	2	2	3	2	1.6
64	4	1	2	2	2	0.75	28.57	28.57	1.6	0.02	36.67	28.6	1.6	56.3	0	5	2	4	2	3	2	2	3	1.6
67	4	2	3	5	2	0.7	28.43	28.43	1.6	0.02	39	28.4	1.5	50.9	3	99.12	1	4	2	1	3	4	2	-1.5
68	4	2	3	5	1	0.57	28.43	28.43	1.2	0.02	39	28.4	1.2	35.2	3	99.12	1	4	2	1	3	4	2	-1.8
69	4	1	3	3	1	0.9	28.43	28.43	1	0.02	39	28.4	1.3	40.3	3	99.12	1	7	2	1	3	5	2	-1.7
70	4	1	2	1	2	1.23	28.43	28.43	1	0.02	39	28.4	1.5	50.9	0	5	1	3	3	2	1	4	2	1.5
71	4	1	3	3	3	0.55	28.43	28.43	0.7	0.02	39	28.4	-0.5	10.2	0	5	1	4	2	1	2	2	3	-0.5

72	4	1	3	5	3	0.73	28.43	28.43	0.7	0.02	39	28.4	-0.1	5.2	3	99.12	1	4	2	4	2	3	3	-3.1
73	4	1	3	5	3	0.65	28.68	28.68	1.4	0.02	42.43	28.7	1.5	50.9	1	26.12	1	4	2	1	2	3	3	0.5
74	4	1	2	5	3	0.82	28.43	28.43	0.7	0.02	39	28.4	0	5	3	99.12	1	5	3	1	3	2	3	-3
76	4	1	3	4	3	0.39	28.43	28.43	0.7	0.02	39	28.4	-0.8	18.5	3	99.12	1	4	2	1	3	4	2	-3.8
78	4	2	3	3	3	1.25	28.43	28.43	1	0.02	39	28.4	1.6	56.3	0	5	2	4	2	3	2	3	3	1.6
79	4	2	3	5	3	0.74	28.43	28.43	1.9	0.02	39	28.4	1.7	61.8	3	99.12	1	7	1	1	3	4	2	-1.3
80	4	2	3	5	3	0.37	28.43	28.43	1.2	0.02	39	28.4	0.9	22.1	2	76.76	1	4	2	1	2	4	2	-1.1
81	4	1	4	5	1	0.9	28.43	28.43	0.7	0.02	39	28.4	0.2	5.8	3	99.12	1	4	1	1	3	3	3	-2.8
82	4	2	4	5	1	1.22	28.43	28.43	1.6	0.02	39	28.4	1.7	61.8	3	99.12	1	5	1	1	3	2	3	-1.3
85	4	2	3	5	2	1	28.43	28.43	1.2	0.02	39	28.4	1.5	50.9	0	5	1	4	2	3	2	3	3	1.5
86	4	2	3	3	1	1.17	26.87	26.87	1.4	0.04	44.87	26.9	1.4	45.5	0	5	1	4	1	2	2	1	1	1.4
87	4	1	2	5	2	0.54	26.87	26.87	1	0.04	44.87	26.9	0.4	8.3	1	26.12	1	6	1	1	3	4	2	-0.6
88	4	2	2	5	3	0.33	26.87	26.87	1	0.04	44.87	26.9	0	5	1	26.12	1	3	3	1	2	3	3	-1
89	4	2	2	5	3	0.69	27.18	27.18	1	0.01	44.72	27.2	0.8	18.5	3	99.12	1	6	1	1	3	4	2	-2.2
90	4	3	4	5	1	0.36	26.87	26.87	1	0.04	44.87	26.9	0	5	3	99.12	1	2	3	1	3	2	3	-3
91	4	1	3	5	3	0.95	26.87	26.87	0.7	0.04	44.87	26.9	-0.3	6.9	3	99.12	1	3	1	1	2	2	2	-3.3
92	4	2	3	4	3	0.95	27.18	27.18	1.9	0.01	44.72	27.2	1.6	56.3	0	5	2	4	2	1	2	3	3	1.6
93	4	2	2	4	3	0.95	26.87	26.87	1.9	0.04	44.87	26.9	1.6	56.3	0	5	2	4	2	2	2	3	4	1.6
94	4	2	3	5	3	0.76	27.07	27.07	1.6	0.02	44.35	27.1	1.3	40.3	0	5	2	4	2	1	2	3	4	1.3
95	4	1	3	3	3	1.17	26.87	26.87	0.7	0.04	44.87	26.9	0	5	3	99.12	1	4	2	1	3	2	2	-3
97	4	1	2	2	3	1.87	27.17	27.17	1	0.02	49.2	27.2	1.7	61.8	1	26.12	2	5	2	1	2	3	3	0.7
100	4	2	3	5	3	1	27.07	27.07	1.6	0.02	44.35	27.1	1.5	50.9	0	5	3	4	2	1	2	3	3	1.5
101	4	1	2	4	3	1.09	26.87	26.87	1	0.04	44.87	26.9	1.1	30.5	0	5	2	4	2	1	2	3	4	1.1
102	4	1	2	5	3	0.97	26.87	26.87	1	0.04	44.87	26.9	1	26.1	0	5	2	4	2	1	2	3	3	1
103	4	2	2	3	3	0.95	26.87	26.87	1.2	0.04	44.87	26.9	1.2	35.2	0	5	3	4	2	1	2	3	3	1.2
104	4	2	3	4	3	0.8	26.87	26.87	1	0.04	44.87	26.9	0.8	18.5	1	26.12	2	4	2	1	2	2	3	-0.2
105	4	2	2	4	3	1.06	26.87	26.87	1.6	0.04	44.87	26.9	1.5	50.9	3	99.12	1	3	3	1	3	4	2	-1.5
106	4	2	2	4	3	0.85	26.87	26.87	1.6	0.04	44.87	26.9	1.4	45.5	3	99.12	1	1	3	1	3	2	2	-1.6
107	4	2	3	5	3	0.78	26.87	26.87	1	0.04	44.87	26.9	0.8	18.5	2	76.76	1	4	1	1	3	1	3	-1.2
108	4	2	3	5	3	0.92	26.87	26.87	1.6	0.04	44.87	26.9	1.4	45.5	2	76.76	1	6	1	1	3	4	2	-0.6
109	4	1	3	5	3	0.96	26.87	26.87	1.4	0.04	44.87	26.9	1.3	40.3	3	99.12	1	3	3	1	3	2	2	-1.7
110	4	2	2	4	3	0.33	26.87	26.87	1.6	0.04	44.87	26.9	0.9	22.1	3	99.12	1	3	3	1	3	4	2	-2.1
111	4	2	2	4	3	0.85	26.74	26.74	1	0.02	47.1	26.7	0.8	18.5	3	99.12	2	3	2	1	2	3	3	-2.2
112	4	2	2	4	3	1.2	26.87	26.87	1.6	0.04	44.87	26.9	1.5	50.9	0	5	2	4	2	2	2	3	3	1.5
113	4	1	2	5	3	0.83	26.87	26.87	1.4	0.04	44.87	26.9	1.2	35.2	3	99.12	1	4	2	1	3	2	2	-1.8

114	4	1	3	4	2	1.05	26.87	26.87	1	0.04	44.87	26.9	1.1	30.5	0	5	2	4	2	1	2	3	4	1.1
115	4	2	3	4	2	1.15	26.87	26.87	1	0.04	44.87	26.9	1.2	35.2	0	5	2	4	2	1	2	1	3	1.2
116	4	1	1	3	2	0.98	27.07	27.07	1.9	0.02	44.35	27.1	1.7	61.8	1	26.12	3	5	3	3	3	4	3	0.7
117	4	3	4	5	1	1.06	26.95	26.95	1.6	0.02	44.68	27	1.5	50.9	-1	26.12	2	6	1	2	3	3	2	2.5
118	4	1	1	5	2	0.94	27.1	27.1	1.2	0.03	48.93	27.1	1.2	35.2	0	5	2	5	1	2	3	4	2	1.2
119	4	1	3	3	3	0.94	26.95	26.95	0.7	0.02	44.68	27	-0.3	6.9	3	99.12	1	2	3	1	3	5	1	-3.3
120	4	1	2	2	2	0.97	27.17	27.17	1	0.02	49.2	27.2	1.1	30.5	0	5	1	4	2	2	3	3	3	1.1
121	4	2	4	4	3	0.74	26.9	26.9	1.6	0.04	47.9	26.9	1.3	40.3	3	99.12	1	7	1	2	3	4	2	-1.7
122	4	1	2	2	1	1.07	27.1	27.1	1	0.03	48.93	27.1	1.2	35.2	0	5	2	3	2	2	2	3	3	1.2
123	4	2	3	3	2	1.1	26.78	26.78	1.2	0.04	46.77	26.8	1.3	40.3	3	99.12	1	7	1	1	3	4	2	-1.7
124	4	1	4	5	3	0.67	26.87	26.87	1.2	0.04	44.87	26.9	0.9	22.1	3	99.12	1	5	1	1	3	3	2	-2.1
125	4	2	4	5	3	1.03	26.87	26.87	1.4	0.04	44.87	26.9	1.4	45.5	3	99.12	1	3	3	1	3	2	3	-1.6
126	4	1	4	4	2	0.83	26.95	26.95	1	0.02	44.68	27	0.9	22.1	0	5	1	4	2	2	3	3	3	0.9
127	4	2	4	4	2	0.65	27.17	27.17	1.9	0.02	49.2	27.2	1.5	50.9	3	99.12	1	5	3	1	3	4	2	-1.5
128	4	2	4	4	2	0.75	26.87	26.87	1	0.04	44.87	26.9	0.7	15.3	0	5	3	5	1	1	1	3	4	0.7
129	4	2	4	5	2	1.08	26.87	26.87	1	0.04	44.87	26.9	1.1	30.5	0	5	2	4	1	1	2	1	3	1.1
130	4	2	4	5	3	0.34	26.87	26.87	1	0.04	44.87	26.9	0	5	3	99.12	2	4	2	1	2	2	3	-3
131	4	1	4	4	2	0.42	26.87	26.87	0.7	0.04	44.87	26.9	-1.6	56.3	2	76.76	1	5	1	4	3	4	3	-3.6
132	4	1	4	4	2	0.41	26.87	26.87	0.7	0.04	44.87	26.9	-1.7	61.8	3	99.12	1	6	1	1	2	2	3	-4.7
134	4	1	2	2	1	0.39	26.87	26.87	1.2	0.04	44.87	26.9	0.5	10.2	0	5	2	4	2	2	2	3	3	0.5
135	4	1	2	2	1	0.65	26.87	26.87	0.7	0.04	44.87	26.9	-1	26.1	0	5	2	4	2	2	2	3	3	-1
137	4	2	2	4	1	0.81	26.87	26.87	1	0.04	44.87	26.9	0.8	18.5	3	99.12	1	5	2	2	3	3	2	-2.2
138	4	1	4	4	3	0.95	26.95	26.95	0.7	0.02	44.68	27	-0.3	6.9	1	26.12	2	5	2	2	2	2	3	-1.3
139	4	1	4	5	3	0.84	26.87	26.87	1	0.04	44.87	26.9	0.8	18.5	3	99.12	1	3	2	1	3	3	3	-2.2
140	4	2	4	5	2	0.79	26.87	26.87	1	0.04	44.87	26.9	0.8	18.5	0	5	1	3	2	1	3	4	2	0.8
142	4	1	4	4	3	1.05	26.87	26.87	1	0.04	44.87	26.9	1.1	30.5	1	26.12	1	5	1	2	3	2	3	0.1
143	3	1	2	5	3	0.97	27.02	26.89	2.1	0.2	36.68	27	1.6	56.3	-1	26.12	2	4	2	2	2	2	3	2.6
144	3	2	2	4	3	0.97	27.6	26.89	0.8	0.2	36.65	27.3	0.1	5.2	-1	26.12	2	4	2	2	2	2	3	1.1
145	3	2	3	4	3	1.15	26.93	26.89	1.2	0.2	42.08	26.9	1.2	35.2	-1	26.12	2	4	2	2	2	2	2	2.2
146	3	2	3	3	3	1.03	27.57	26.89	0.8	0.2	37	27.3	0.2	5.8	2	76.76	2	4	2	3	2	2	3	-1.8
147	3	1	2	4	3	1.05	27.57	26.89	1	0.2	37	27.3	0.9	22.1	0	5	2	4	2	2	2	2	2	0.9
148	3	2	3	3	3	0.99	27.15	26.89	0.8	0.2	39.9	27	0	5	1	26.12	2	4	2	2	2	2	2	-1
149	3	1	1	4	3	1.19	27.03	26.89	1.2	0.2	36.82	27	1.2	35.2	-1	26.12	2	4	2	2	2	2	2	2.2
150	3	2	3	3	3	1.25	27.28	26.89	0.8	0.2	41.65	27.1	0.4	8.3	0	5	2	4	2	2	2	2	2	0.4
151	3	1	2	5	3	0.62	26.3	26.89	2.1	0.2	38.43	26.5	1.4	45.5	2	76.76	2	6	1	1	3	3	3	-0.6

152	3	2	4	5	3	1.2	27.02	26.89	1	0.2	36.68	27	1	26.1	-2	76.76	2	4	2	2	2	2	3	3
153	3	1	2	4	3	1.4	27.07	26.89	0.8	0.2	37.28	27	0.5	10.2	2	76.76	2	4	2	2	2	2	2	-1.5
154	3	2	2	3	3	1.06	27.18	26.89	0.8	0.2	41.57	27.1	0.2	5.8	2	76.76	2	4	2	2	2	2	3	-1.8
155	3	2	4	5	2	1.31	27.18	26.89	2.1	0.2	41.57	27.1	1.8	67	0	5	2	4	2	2	2	3	2	1.8
156	3	2	3	5	3	1.2	27.18	26.89	2.1	0.2	41.57	27.1	1.8	67	-1	26.12	2	4	2	2	2	3	2	2.8
157	3	2	3	4	1	1.13	24.74	26.89	1	0.2	44.11	25.6	0.6	12.5	-2	76.76	2	4	2	2	3	3	2	2.6
158	3	3	4	3	1	1.22	26.32	26.89	2.1	0.2	38.62	26.5	1.7	61.8	0	5	2	6	2	3	3	4	3	1.7
159	3	2	3	3	2	1.47	26.56	26.89	1	0.2	39.73	26.7	1.2	35.2	0	5	3	4	2	2	2	2	2	1.2
160	3	3	3	3	2	1.1	27.02	26.89	1.2	0.2	36.68	27	1.1	30.5	0	5	2	6	3	2	3	4	2	1.1
161	3	2	3	3	1	1.08	26.41	26.89	1.2	0.2	39.96	26.6	1	26.1	2	76.76	3	5	2	3	1	3	2	-1
162	3	2	3	3	3	1.26	26.93	26.89	1	0.2	42.08	26.9	1.1	30.5	0	5	2	4	2	2	1	1	4	1.1
163	3	2	3	5	3	1.11	26.9	26.89	0.8	0.2	41.83	26.9	0.2	5.8	0	5	2	4	2	1	2	2	3	0.2
164	3	2	2	4	3	1.27	26.92	26.89	1	0.2	41.73	26.9	1.1	30.5	2	76.76	2	1	2	1	2	3	3	-0.9
165	3	1	2	4	2	1.34	26.51	26.89	1	0.2	39.8	26.7	1.1	30.5	-1	26.12	2	4	2	2	2	2	3	2.1
166	3	2	2	3	3	1.16	26.59	26.89	0.8	0.2	39.83	26.7	0.2	5.8	0	5	2	4	2	2	2	3	3	0.2
167	3	1	2	2	3	1.32	27.07	26.89	0.8	0.2	41.42	27	0.5	10.2	0	5	2	4	2	2	2	3	3	0.5
168	3	1	2	2	3	1.37	27.07	26.89	0.8	0.2	41.42	27	0.5	10.2	0	5	2	4	2	2	2	4	3	0.5
169	3	1	3	4	3	1.36	27.07	26.89	0.8	0.2	41.42	27	0.5	10.2	0	5	2	4	2	2	2	3	3	0.5
170	3	1	2	4	3	1.16	27.1	26.89	0.8	0.2	38.77	27	0.2	5.8	0	5	2	4	2	2	2	3	3	0.2
171	3	2	3	4	3	1.31	26.92	26.89	0.8	0.2	41.73	26.9	0.4	8.3	0	5	2	3	3	1	2	3	3	0.4
172	3	2	3	3	3	1.34	27.18	26.89	0.8	0.2	41.57	27.1	0.5	10.2	0	5	2	4	2	2	2	3	3	0.5
173	3	1	2	2	3	1.03	27.07	26.89	0.8	0.2	37.28	27	0	5	0	5	2	4	2	2	2	3	3	0
174	3	2	3	4	3	1.17	27.23	26.89	0.8	0.2	41.43	27.1	0.3	6.9	0	5	2	4	2	2	2	3	3	0.3
175	3	2	3	5	2	0.85	26.92	26.89	1	0.2	41.73	26.9	0.6	12.5	0	5	1	4	2	2	2	3	4	0.6
176	3	2	1	2	1	0.79	27.03	26.89	2.1	0.2	41.5	27	1.6	56.3	1	26.12	2	6	2	4	3	1	1	0.6
177	3	3	2	3	3	1.47	27.05	26.89	2.1	0.2	36.88	27	1.8	67	0	5	3	5	3	4	3	2	1	1.8
178	3	1	2	3	2	0.81	26.61	26.89	1	0.2	39.97	26.7	0.5	10.2	-1	26.12	3	4	2	3	3	1	1	1.5
179	3	2	2	5	2	0.87	26.93	26.89	2.1	0.2	42.08	26.9	1.6	56.3	2	76.76	3	4	2	2	1	2	4	-0.4
180	3	2	2	2	3	0.82	26.92	26.89	1	0.2	41.73	26.9	0.6	12.5	3	99.12	1	3	3	1	2	3	3	-2.4
181	3	3	4	4	2	0.78	26.59	26.89	1	0.2	39.83	26.7	0.4	8.3	-1	26.12	2	4	3	2	2	2	3	1.4
182	3	3	3	3	3	1.15	26.32	26.89	2.1	0.2	38.62	26.5	1.7	61.8	0	5	3	5	2	2	2	3	2	1.7
183	3	3	4	5	2	1.18	26.37	26.89	2.1	0.2	38.68	26.6	1.7	61.8	-1	26.12	2	6	2	3	2	4	3	2.7

Figure A: Research Ethics

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

University of Nottingham Ningbo

Research Ethics Checklist for Staff and Research Students

[strongly informed by the ESRC (2012) *Framework for Research Ethics*]

A checklist should be completed for **every** research project or thesis where the research involves the **participation of people, the use of secondary datasets or archives relating to people and/or access to field sites or animals**. It will be used to identify whether a full application for ethics approval needs to be submitted.
You must not begin data collection or approach potential research participants until you have completed this form, received ethical clearance, and submitted this form for retention with the appropriate administrative staff.

The principal investigator or, where the principal investigator is a student, the supervisor, is responsible for exercising appropriate professional judgement in this review.

Completing the form includes providing brief details about yourself and the research in Sections 1 and 2 and ticking some boxes in Sections 3 and/or 4, 5, 6. **Ticking a shaded box in Sections 3, 4, 5 or 6 requires further action by the researcher**. Two things need to be stressed:

- Ticking one or more shaded boxes does **not** mean that you cannot conduct your research as currently anticipated; however, it does mean that further questions will need to be asked and addressed, further discussions will need to take place, and alternatives may need to be considered or additional actions undertaken.
- Avoiding the shaded boxes does **not** mean that ethical considerations can subsequently be 'forgotten'; on the contrary, research ethics - for everyone and in every project – should involve an ongoing process of reflection and debate.

The following checklist is a starting point for an ongoing process of reflection about the ethical issues concerning your study.

SECTION 1: THE RESEARCHER(S)

1.1: Name of principal researcher: Boyu Du ([illegible])

1.2: Status: ☐ Staff

☑ Postgraduate research student Master by research in Sustainable Building Technology.

1.3: School/Division: ABE

1.4: Email address: Boyu.Du@nottingham.edu.cn

1.5: Names of other project members (if applicable): n/a

1.6: Names of Supervisors (if applicable): Liang Xia

	Yes	No
1.7: I have read the University of Nottingham's *Code of Research Conduct and Research Ethics* (2010) and agree to abide by it: http://www.nottingham.edu.cn/en/research/researchethics/ethics-approval-process.aspx	☑	☐
1.8: (If applicable) I have read the University of Nottingham's *e-Ethics@Nottingham: Ethical Issues in Digitally Based Research* (2012) and agree to abide by it. http://www.nottingham.edu.cn/en/research/documents/e-ethics-at-the-university-of-nottingham.pdf	☑	☐
1.9: When conducting research on people (Section 5) I will prepare both a *participant consent form* as well as a *participant information sheet*. I am aware that the following templates are available on the Ethics webpage: http://www.nottingham.edu.cn/en/research/researchethics/ethics-approval-process.aspx • Participant consent form 1 • Participant Information Sheet English and Chinese	☑	☐

SECTION 2: THE RESEARCH

2.1: **Title of project:**

Thermal comfort in hospital (patients, visitors and doctors)

Please provide brief details (50-150 words) about your proposed research, as indicated in each section

2.2: **Research question(s) or aim(s)**

1. I will collect subjective data by using questionnaires to analyse people's Thermal comfort situation in one hospital building.

2. I will check the temperature, humidity, ventilation and CO_2 inside building to tell whether they have relationship with people's Thermal comfort.

2.3: **Summary of method(s) of data collection**

1. ~~use~~ Using questionnaires related to thermal comfort issues to collect subjective data. What the ~~pe~~ participants wear and what they do before writting questionnaires are also included.

2. put sensors in one ward, doctor's office and nurse station to collect objective data.

2.4: **Proposed site(s) of data collection**

Building: In a hospital in Beijing China.

Time: From ~~May~~ March 2018 to May 2018.

2.5: **How will access to participants and/or sites be gained?**

1. Ask staff in this hospital to help us to collect questionnaires from staff, patients, visitors.

2. Before we collect data, we will go to the research department of this hospital to sign an agreement.

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

SECTION 3: RESEARCH INVOLVING USE OF SECONDARY DATASETS OR ARCHIVES RELATING TO PEOPLE

If your research involves use of secondary datasets or archives relating to people all questions in Section 3 **must** be answered. If it does not, please tick the 'not relevant' box and go to Section 4.

NOT RELEVANT	☑

Please answer each question by ticking the appropriate box.

	Yes	No
3.1: Is the risk of disclosure of the identity of individuals low or non-existent in the use of this secondary data or archive?	☐	☐
3.2: Have you complied with the data access requirements of the supplier (where relevant), including any provisions relating to presumed consent and potential risk of disclosure of sensitive information?	☐	☐

SECTION 4: RESEARCH INVOLVING ACCESS TO FIELD SITES AND ANIMALS

If your research involves access to field sites and/or animals all questions in Section 4 **must** be answered. If it does not, please tick the 'not relevant' box and go to Section 5.

NOT RELEVANT	☑

Please answer each question by ticking the appropriate box.

	Yes	No
4.1: Has access been granted to the site?	☐	☐
4.2: Does the site have an official protective designation of any kind?	☐	☐
If yes, have the user guidelines of the body managing the site a) been accessed?	☐	☐
b) been integrated into the research methodology?	☐	☐
4.3: Will this research place the site, its associated wildlife and other people using the site at any greater physical risks than are experienced during normal site usage?	☐	☐
4.4: Will this research involve the collection of any materials from the site?	☐	☐
4.5: Will this research expose the researcher(s) to any significant risk of physical or emotional harm?	☐	☐
4.6: Will the research involve vertebrate animals (fish, birds, reptiles, amphibians, mammals) or the common octopus (*Octopus vulgaris*) in any capacity?	☐	☐

If yes, will the research with vertebrates or octopi involve handling or interfering with the animal in any way or involve any activity that may cause pain, suffering, distress or lasting harm to the animal?	☐	☐

SECTION 5: RESEARCH INVOLVING THE PARTICIPATION OF PEOPLE

If your research involves the participation of people all questions in Section 4 **must** be answered.

Please answer each question by ticking the appropriate box.

A. General Issues

	Yes	No
5.1: Does the study involve participants age 16 or over who are unable to give informed consent? (e.g. people with cognitive impairment, learning disabilities, mental health conditions, physical or sensory impairments?	☐	☑
5.2: Does the research involve other vulnerable groups such as children (**aged under 16**) or those in unequal relationships with the researcher? (e.g. your own students)	☐	☑
5.3: Will this research require the cooperation of a gatekeeper* for initial access to the groups or individuals to be recruited?	☐	☑
5.4: Will this research involve discussion of sensitive topics (e.g. sexual activity, drug use, physical or mental health)?	☐	☑
5.5: Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?	☐	☑
5.6: Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	☐	☑
5.7: Will this research involve people taking part in the study without their knowledge and consent at the time?	☐	☑
5.8: Does this research involve the internet or other visual/vocal methods where people may be identified?	☐	☑
5.9: Will this research involve access to personal information about identifiable individuals without their knowledge or consent?	☐	☑
5.10: Does the research involve recruiting members of the public as researchers (participant research)?	☑	☐
5.11: Will the research involve administrative or secure data that requires permission from the appropriate authorities before use?	☐	☑
5.12: Is there a possibility that the safety of **the researcher** may be in question?	☐	☑
5.13: Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?	☐	☑

**Gatekeeper- a person who controls or facilitates access to the participants*

B. Before starting data collection

	Yes	No
6.12: My full identity will be revealed to all research participants.	☐	☑
6.13: All participants will be given accurate information about the nature of the research and the purposes to which the data will be put. (*An example of a Participant Information Sheet is available for you to amend and use* at xxxxx) *http://www.nottingham.edu.cn/en/research/documents/participant-information-sheet-in-english-and-chinese.doc*	☑	
6.14: All participants will freely consent to take part, and, where appropriate, this will be confirmed by use of a consent form. (An example of a Consent Form is available for you to amend and use at: http://www.nottingham.edu.cn/en/research/researchethics/ethics-approval-process.aspx)	☑	☐
6.15: All participants will freely consent to take part, but due to the qualitative nature of the research a formal consent form is either not feasible or is undesirable and alternative means of recording consent are proposed.	☐	☑
6.16: A signed copy of the consent form or (where appropriate) an alternative record of evidence of consent will be held by the researcher.	☐	
6.17: It will be made clear that declining to participate will have no negative consequences for the individual.	☑	☐
6.18: Participants will be asked for permission for quotations (from data) to be used in research outputs where this is intended.	☑	☐
6.19: I will inform participants how long the data collected from them will be kept.	☑	
6.20: Incentives (other than basic expenses) will be offered to potential participants as an inducement to participate in the research. (Here any incentives include cash payments and non-cash items such as vouchers and book tokens.)	☐	☑
6.21: For research conducted within, or concerning, organisations (e.g. universities, schools, hospitals, care homes, etc) I will gain authorisation in advance from an appropriate committee or individual.	☑	☐

C. During the process of data collection

	Yes	No
6.25: I will provide participants with my University contact details, and those of my supervisor (*where applicable*) so that they may get in touch about any aspect of the research if they wish to do so.	☐	
6.26: Participants will be guaranteed anonymity only insofar as they do not disclose any illegal activities.	☑	☐
6.27: Anonymity will not be guaranteed where there is disclosure or evidence of significant harm, abuse, neglect or danger to participants or to others.	☑	☐
6.28: All participants will be free to withdraw from the study at any time, including withdrawing data following its collection.	☑	☐

	Yes	No
6.29: Data collection will take place only in public and/or professional spaces (e.g. in a work setting	☑	☐
6.30: Research participants will be informed when observations and/or recording is taking place.	☑	☐
6.31: Participants will be treated with dignity and respect at all times.	☑	☐

D. After collection of data

	Yes	No
6.32: Where anonymity has been agreed with the participant, data will be anonymised as soon as possible after collection.	☑	☐
6.33: All data collected will be stored in accordance with the requirements of the University's Code of Research Conduct	☑	☐
6.34: Data will only be used for the purposes outlined within the participant information sheet and the agreed terms of consent.	☑	☐
6.35: Details which could identify individual participants will not be disclosed to anyone other than the researcher, their supervisor and (if necessary) the Research Ethics Panel and external examiners without participants' explicit consent.	☑	☐

E. After completion of research

	Yes	No
6.37: Participants will be given the opportunity to know about the overall research findings.	☐	☐
6.38: All hard copies of data collection tools and data which enable the identification of individual participants will be destroyed.	☐	☐

*If you have **not** ticked any shaded boxes,* please send the completed and signed form to the School's Research Ethics Officers, with any further required documents, for approval and record-keeping.

If you have ticked any shaded boxes **you will need to describe more fully how you plan to deal with the ethical issues raised by your research.** Issues to consider in preparing an ethics review are given below. Please send this completed form to the Research Ethics Officer who will decide whether your project requires further review by the UNNC Research Ethics Sub-Committee and/or whether further information needs to be provided.
Please note that it is your responsibility to follow the University's ***Research Code of Conduct*** and any relevant academic or professional guidelines in the conduct of your study. **This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data. For guidance and UK regulations on the latter, please refer to** the *Data Protection Policy and Guidelines* of the University of Nottingham:

Policy - http://www.nottingham.ac.uk/%7Ebrzdpa/local/dp-policy.doc

Guidelines -http://www.nottingham.ac.uk/~brzdpa/local/dp-guidance.doc

Any significant change in the project question(s), design or conduct over the course of the research should be notified to the School Research Ethics Officer and may require a new application for ethical approval.

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

Signature of Principal Investigator/Researcher: Boyu Du 2018.03.01.
Signature of Supervisor (where appropriate): [signature]
Date 2018.3.1

Research Ethics Panel response

- ☐ the research can go ahead as planned
- ☐ further information is needed on the research protocol (see details below)
- ☐ amendments are requested to the research protocol (see details below)

School REO.. Date ....

A. LIST OF POINTS TO CONSIDER WHEN SUBMITTING AN ETHICS REVIEW (taken from ESRC (2012) *Framework for Research Ethics*).

Risks

1. Have you considered risks to: To the whole question in Question one!
   the research team? No, we don't have any risk. We respect our participants
   the participants? *Eg harm, deception, impact of outcomes* and allow them to do
   the data collected? *Eg storage, considerations of privacy, quality* everything they want
   the research organisations, project partners and funders involved?
2. Might anyone else be put at risk as a consequence of this research? No.
3. What might these risks be? No.
4. How will you protect your data at the research site and away from the research site? Change it to empty.
5. How can these risks be addressed?

Details and recruitment of participants

6. What types of people will be recruited? *Eg students, children, people with learning disabilities, elderly?* Staff in hospital who knows and got familiar with my research
7. How will the competence of participants to give informed consent be determined?
8. How, where, and by whom participants will be identified, approached, and recruited? I will ask the staff in this hospital who got familiar with this research to help and let them to collect questionnaires.
9. Will any unequal relationships exist between anyone involved in the recruitment and the potential participants? No
10. Are there any benefits to participants? NO
11. Is there a need for participants to be de-briefed? By whom? No.

Research information

12. What information will participants be given about the research? What is this research and the purpose of this research will be given
13. Who will benefit from this research? No
14. Have you considered anonymity and confidentiality? Yes.
15. How will you store your collected data? Scanned Copy.
16. How will data be disposed of and after how long?
    I will analyse these data after I collect it to finish dissertation in 2018 and It will be kept for 10 years.

17. Are there any conflicts of interest in undertaking this research? *Eg financial reward for outcomes etc.* No

18. Will you be collecting information through a third party? No.

Consent

19. Have you considered consent? Yes

20. If using secondary data, does the consent from the primary data cover further analysis? I donot use secondary data.

21. Can participants opt out? Yes.

22. Does your information sheet (or equivalent) contain all the information participants need? Yes

23. If your research changes, how will consent be renegotiated? Tell the hospital the true situ

Ethical procedures

24. Have you considered ethics within your plans for dissemination/impact? Yes.

25. Are there any additional issues that need to be considered ? *Eg local customs, local 'gatekeepers', political sensitivities* No.

26. Have you considered the time you need to gain ethics approval? Yes.

27. How will the ethics aspects of the project be monitored throughout its course? ~~Tell the~~

28. Is there an approved research ethics protocol that would be appropriate to use?

29. How will unforeseen or adverse events in the course of research be managed? *Eg do you have procedures to deal with any disclosures from vulnerable participants?*

27. Tell the people related to this research directly.

28. Yes.

29. Just calm down and respect my participants.