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Thermal perceptions of the elderly, use patterns and satisfaction with open space

Abstract

The elderly is a main user group of open space. Well maintained open spaces can increase their physical health and well-being. It is recognized that thermal perception has an essential impact on people's outdoor activities and use of open space. However, the specific association between influencing factors and the elderly's thermal perception and use of open space has not yet been fully investigated. On-site measurements of thermal conditions were carried out and 485 questionnaire surveys were conducted in six parks in two districts in Hong Kong. The ordered probit model and the binary logistics regression model were employed to investigate the relationship between the factors and the elderly's thermal perceptions, using the measure of thermal comfort, thermal sensation and thermal acceptability and use patterns and satisfaction with using open space. The study adopted a comprehensive framework, which included individual, physical and social and psychological factors. The results show the factors which influence the elderly's thermal perceptions vary in the winter and summer and there is a significant association between thermal acceptability and satisfaction with open space. Under the trend of global warming, more attention should be paid to mitigate summer heat stress in outdoor space. The empirical findings of the elderly’s thermal perceptions and use patterns of parks in the summer provide insight for urban planners when considering flexible and responsive designs that reflect the special needs of the elderly.

Keywords: thermal perceptions, elderly, use patterns, satisfaction, open space

1. Introduction

Thermal perception is an important consideration when providing usable and comfortable spaces for human occupants, not only in indoor environments but also in outdoor environments. Understanding thermal comfort conditions in outdoor urban spaces can be complex. Thermal perception primarily refers to the satisfaction of the subject and takes into account the air temperature, the radiant temperature, the air velocity and the relative humidity of the perceived environment to the person at his/her metabolic rate and the kind of clothing he/she is wearing (Fanger, 1970). In the design and planning of outdoor open spaces, thermal comfort can effectively increase the use of outdoor spaces and encourage activities and social interactions (Nikolopoulou, Baker & Steemers, 2001; Thorsson, Lindqvist & Lindqvist, 2004).

The elderly is an important group of outdoor open space users (Pleson et al., 2014). An outdoor environment is also a special place for the elderly to socially interact, which helps contribute to their physical health and well-being. As such, enhancing the use of outdoor spaces can help the elderly to remain active, communicate with others and enjoy social lives (Sugiyama & Thompson, 2007). Outdoor thermal comfort is one aspect that has a major impact on the elderly’s use of outdoor spaces, activities and quality of life.

Many previous studies have looked at the influential factors of thermal comfort and their relationship with outdoor activities in urban parks and squares. Research has pointed out that only looking at physiological factors is inadequate to understanding thermal comfort conditions in outdoor spaces (Nikolopoulou et al., 2001). Moreover, there are inconsistencies about the findings. Most importantly, however, very few studies have focused specifically on the elderly population and their special physical and social needs and their seasonal preferences. All these factors need to be carefully investigated.

Hong Kong is a dense urban city where living areas and open spaces are not adequate for the needs of the population. In 2015, the average living space per person, i.e., public rental housing and private housing, was 13m^2 and 20m^2, respectively. Thus, because of inadequate living areas, people, in general, prefer to spend their time in public spaces, especially the elderly who have fewer financial resources (Yung et al., 2016). Based on the Hong Kong 2030+ study (Planning Department, 2016), local open space and district open space per person amounts to 1.64 m^2 and 1.07 m^2, respectively, which is lower than other high density Asian cities like Shanghai, Singapore and Tokyo. Based on the Hong Kong Population Projections 2017-2066 (Census and Statistics Department, 2017), the proportion of elderly people is projected to keep rising from 15.9 % in 2016 to 33.6% in 2066. Examining the needs of this growing population group has become a matter of urgency. This severe demographic change is also happening in many developed cities, e.g., Japan, Singapore, etc. Furthermore, it is widely observed that the majority of users of open spaces (in particular public parks) in Hong Kong are senior citizens. Therefore, providing high quality open spaces where the elderly can feel comfortable is important in high density cities like Hong Kong. Thus, this study focuses on examining thermal perceptions and use patterns of the elderly regarding open spaces in Hong Kong.

Given the above, the objectives of this research study are formulated as follows: (1) to identify the influencing factors on the elderly's outdoor thermal perceptions, (2) to examine the association between the elderly's thermal perceptions and use patterns and satisfaction with using open space, (3) to compare the different preferences of the elderly during the winter and summer months in Hong Kong.

2. Literature Review

2.1 The effects of thermal environments on the elderly's open space use and their social behavior

Previous studies have shown that thermal environment has a significant impact on people's use of open space, such as users' preferences and activities. Thermal perceptions are most commonly used to reflect the thermal environment and can be evaluated using three scales: thermal comfort, thermal sensation and thermal acceptability (Lin, 2009; Shooshtarian & Ridley, 2016). Thermal comfort is defined by ASHRAE (2010) as "the condition of mind that expresses satisfaction with the thermal environment. Thermal comfort can be partially influenced by different contextual and cultural factors." Thermal sensation is a standard parameter in most thermal experiments and is a subjective evaluation of people's conscious feelings (ASHRAE, 2010). Thermal acceptability is defined as "an environment that a substantial majority of the occupants would find thermally acceptable" (ASHRAE, 2010).

Use of open space is affected by micro-meteorological factors, including air temperature and sunshine exposure in winter (Chen et al., 2015) and air temperature and solar radiation (Nikolopoulou & Lykoudis,2007), while the effect of wind speed and relative humidity is comparatively weak.

Generally, research has found that users of open space prefer to engage in intense activities in cool environments (Huang et al., 2016), thus, thermal perception of the environment influences length of time spent in outdoor areas (Nikolopoulou & Steemers, 2003). However, very little research has studied specifically the elderly's thermal preferences in outdoor environments.

Some studies have indicated that the elderly have special thermal sensations (Huang et al., 2016; Shooshtarian & Ridley, 2016), although other studies have indicated that the correlation between age and thermal sensation is low (Indraganti & Rao, 2010). Research has found that the elderly usually feel cooler than those who are younger (Wong et al., 2009). Studies also indicate that the elderly prefer higher temperatures than younger adults in indoor thermal environments (Alves, Duarte & Goncalves, 2016) because they are less tolerant of the cold (Huang et al., 2016). Some studies also claim that the effects of age can be accounted for or reduced by differences in metabolism, activities and clothing adjustment based on people's health condition (Alves, Duarte & Goncalves, 2016; Hoof & Hensen, 2006).

Research has also pointed out that the acceptable range of temperatures for the elderly during the summer months is narrower than for the young (Hwang & Chen, 2010). Generally, with age, people show an increase of discomfort level with the thermal environment (Andrade, Alcoforado, & Oliveira, 2011). In other words, elderly people have lower thermal non-acceptance levels than younger people (Indraganti & Rao, 2010). Seasons also have an impact on the elderly's thermal comfort. It has been shown that the elderly are more sensitive to summer heat and more tolerant of autumn and winter, as the presence of the elderly in public squares is higher during the autumn and winter months (Nikolopoulou & Lykoudis, 2007).

3. Theoretical framework

3.1 Influential factors on thermal perceptions

Previous literature has recognized that thermal perceptions can be affected by physical factors, individual factors and social and psychological factors. However, the special needs of the elderly have not been fully understood. Very little research has integrated the different domains and influential factors in one single study. This study proposes a conceptual framework (Figure 1) which demonstrates the relationship between the different factors and the use and satisfaction with open space by the elderly. The three major groups of factors are explained in the following section.

3.1.1 Physical factors

Physical factors, consisting of air temperature, wind speed, relative humidity, solar radiation, clothing and activity, have been found to exert a collective impact on outdoor thermal comfort, however one single parameter alone is not sufficient to fully explain the impact of thermal comfort (Nikolopoulou & Lykoudis, 2006).

It is indicated that sunshine and high temperatures increase the use of open spaces in the winter and are positively associated with people's thermal sensation (Chen et al., 2015). Relative humidity is usually not treated as an important factor of thermal comfort, except in high air temperatures and relative humidity conditions (Andrade, Alcoforado & Oliveira, 2011). Wind speeds of 0.9–1.30 m/s improve the wind environment in urban areas in Hong Kong (Ng & Cheng, 2012).

In addition, shaded locations give people better thermal comfort in spring, summer and autumn, while people feel more thermally comfortable in less shaded locations during the winter (Martinelli et al., 2015; Hwang et al., 2011). Shaded areas also lead to higher park attendance, compared to unshaded areas (Lin et al., 2012).

Level of clothing insulation, as well as activity, are also essential foundations of heat thermal comfort (ASHRAE, 2010). It was found that people tend to change their clothing level and activity level to adjust to and achieve thermal comfort (Lin, Lin & Hwang, 2013). Most people tend to engage in light activities in hot environments and change to intensive activities in moderate or cold environments (Huang et al., 2016).

3.1.2 Individual factors

Individual factors include age, gender, education level and economic level. The majority of studies have shown that with increase of age, people become less sensitive to heat or cold stress (Krügerand & Rossi, 2011), while some studies show that the elderly feel thermal discomfort more easily (Andrade et al., 2011; Indraganti & Rao, 2010). Shooshtarian and Ridley (2016) have indicated that age group has an effective influence on thermal perception because of people's experiences during different stages of their lives. In contrast, other studies declare that no significant influence has been found (Knez & Thorsson, 2006).

It has been indicated that women usually have higher thermal sensation, as well as thermal acceptability, than men (Indraganti & Rao, 2010; Wong et al., 2009). In addition, males prefer more insulating clothing in warm environments compared to females (Bröde et al., 2012). However, some scholars state that the responses of males and females are similar when in comfortable thermal conditions (Krüger & Rossi, 2011).

Aljawabra and Nikolopoulou (2010) indicate that level of education has a negative correlation with people's thermal comfort, while other studies found that there is no analytical correlation between thermal sensation and level of education in indoor and outdoor environments (Wang et al., 2010; Taib et al., 2010).

It was found that lower economic classes usually have higher thermal acceptability than others (Indraganti & Rao 2010). On the other hand, some scholars have stated that people with high economic levels have more resources for alternative thermal options in uncomfortable environments (Maras et al., 2014).

3.1.3 Social and psychological factors

Companionship is an important social factor that can impact people's thermal perception. It was found that people with no companionship feel more thermally uncomfortable in outdoor open spaces than people with companionship (Maras et al., 2014; Aljawabra & Nikolopoulou, 2010).

Thermal history and memory have an impact on people's thermal acceptability and adaptation. Studies confirm that local citizens have a high tolerance of different thermal conditions and people who live longer are more tolerant of the cold in Shanghai in the winter (Chen et al., 2015). There have been similar findings in different European countries (Nikolopoulou & Lykoudis, 2006).

Why the elderly visit open spaces also affects their thermal perceptions. In previous studies it was found that there are common reasons for visiting open spaces, including social, physical, spatial, design and thermal aspects. Social reasons include visiting parks for social interaction, meeting friends or habit (Kweon et al., 1998). Physical reasons include doing exercise, improving health and participating in activities (Sugiyama & Thompson, 2008). Spatial reasons mean that the elderly go to parks because of their proximity and for exercise (Sugiyama et al., 2009). The elderly also go to parks because of the design and facilities, such as greenery (Kemperman & Timmermans, 2014) and shaded areas, sunlight and fresh air (Ng & Cheng, 2012). Cohen et al. (2013) have pointed out that, for psychological reasons, visitors expect a better thermal environment in open spaces. People visiting open spaces because of thermal reasons in the winter have higher expectations of the thermal environment.

Figure 1: Conceptual framework of the influential factors that affect the elderly's thermal sensation/comfort/acceptability and use and satisfaction of using open space

3.2 Climate background of Hong Kong

Hong Kong is in a typical humid subtropical area. Figure 2 shows the air temperature and humidity characteristics of Hong Kong in 1981-2010. The mean air temperature was highest in July at 28.8℃ on average (39.8℃ in 2016), while the lowest was 16.3℃ in January (15.5℃ in February 2016). The peak mean maximum air temperature was 31.4℃ (32.6℃ in 2016) and the bottom mean minimum air temperature was 14.5℃ (13.4℃ in 2016). The 'cold season' in this study was the period between December to

February based on recorded low air temperatures, while the 'hot season' was the period between May to October.

Based on the climate data collected by the Hong Kong Observatory's climate station in Kwun Tong, the mean air temperature was 18.2℃ and 28.6℃ in winter (January 2017) and summer (June 2017), respectively, while mean wind speed was 3.25m/s and 2.86m/s, respectively. In Tseung Kwan O, the mean air temperature was 17.9℃ and 28.4℃ in winter and summer, respectively, while mean wind speed was 1.78m/s and 1.53m/s, respectively.

Figure 2: Monthly Mean/Maximum/Minimum air temperatures and mean relative humidity in Hong Kong (1981-2010)

Source: Hong Kong Observatory, Hong Kong

The descriptive statistics of PET value are shown in Table 1. It is clearly indicated that based on the grade of physiological stress described in the study carried out in Taiwan (Lin & Matzarakis, 2008), in winter 92.3% of the PET of present study fell within areas from 'extreme cold stress' to 'slight cold stress', and in the summer, 71.7% of PET fell within areas from 'slight heat stress' to 'moderate heat stress'. The data collected in this study can gauge that winter conditions fall within areas of cold thermal stress and summer conditions fall within heat thermal stress, which reflect typical thermal conditions in Hong Kong.

Table 1 PET and grade of physiological stress, according to Lin and Matzarakis, 2008

PET	Grade of physiological stress	Winter		Summer	
		Percentage (%)	Cumulative percentage (%)	Percentage (%)	Cumulative percentage (%)
<14	Extreme cold stress	23.0	23.0	---	---
14-18	Strong cold tress	35.3	58.3	---	---
18-22	Moderate cold stress	24.3	82.6	---	---

22-26	Slight cold stress	9.8	92.3	.5	.5
26-30	No thermal stress	3.4	95.7	21.0	21.5
30-34	Slight heat stress	1.7	97.4	57.5	79.0
34-38	Moderate heat stress	1.7	99.1	14.2	93.2
38-42	Strong heat stress	.9	100.0	5.9	99.1
>42	Extreme heat stress	---	---	.9	100.0

The grade of physiological stress is based on a study in Taiwan, which has similar climate conditions to Hong Kong (see Lin, T. P., & Matzarakis, A. (2008). Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. *International Journal of Biometeorology*, 52(4), 281-290.

4. Methodology

The methodology used in this study has an international standing in the field of research. The thermal environment survey employed has been widely used and verified by other scholars in different climate zones, such as Wuhan (Huang et al., 2016), Shanghai (Chen et al., 2015), Hong Kong (Ng & Cheng, 2012), Taichung (Lin, 2009), Rome (Martinelli et al., 2015), Brazil (Hirashima, de Assis, & Nikolopoulou, 2016) and the RUROS project in Europe (Nikolopoulou & Lykoudis, 2006). The methodology is divided into two parts: the micro-climate measurement and the guided user questionnaire survey.

4.1 Micro-climate measurement

During the field measurement, air temperature (℃), relative humidity (%), globe temperature (℃), solar radiation (W/m^2) and wind velocity (m/s) were measured and recorded. The HOBO U23 Prov2 Temperature/Relative Humidity Data Logger with weatherproof temperature and relative humidity sensors (Onset Computer Corporation, Massachusetts, United States) was used to measure air temperature and humidity. Solar radiation shields and proper shields were installed in the station to protect the sensors from direct sunlight and rain, as well as to minimize the radiative exchange between equipment and environments. In addition, a 3D ultrasonic anemometer (Dantec Dynamics A/S, Skovlunde, Denmark) was used to record the wind velocity and direction. The globe temperature was calculated using a globe thermometer with a 40 mm grey table tennis ball and temperature sensor (Onset Computer Corporation, Massachusetts, United States). Furthermore, Silicon Pyranometer (Onset Computer Corporation, Massachusetts, United States) were used to measure solar radiation. All these sensors complied with the WMO, NO.8 standard (Jarraud, 2008). The sensors were all placed in one fixed weather station at the center of an unshaded area in each of the study sites during the time the questionnaire surveys were conducted. All instruments were placed at a height of 1.1m above the ground, following the instructions of ISO 7726 (ISO, 1998), and were tested and calibrated before the survey. Figure 3 shows the fixed weather station.

Figure 3: The fixed weather station

4.2 User questionnaire survey

The primary objective of the questionnaire survey was to obtain the elderly's subjective opinions of thermal environment and outdoor activity levels in open spaces. The subjects of the survey were people using community open spaces who were 65 or older and were willing and competent to take part in the survey. The study focused on people aged 65 or older, because they are generally seen as the target population in the planning of services for older persons in Hong Kong (Census and Statistics Department, 2018).

The questionnaire consisted of five parts. The first part was observed and completed by the interviewer, including time, site, weather conditions, gender, housing, companionship, position, clothing level and activity of respondents. The clothing level of the subjects was recorded using a checklist extracted and modified from ISO 7730 and ASHRAE 55-2010, and the clo value (I_{cl}) was used to evaluate clothing insulation during the data analysis. The activity was also recorded using the modified form ISO 7730 and ASHRAE 55-2010.

The second part of the questionnaire asked for personal information, including age, education background, monthly expenditure and self-reported health. The option of health was extracted from a 36-Item Short Form Health Survey (SF-36) questionnaire (Lyons, Perry & Littlepage, 1994). The third part of the questionnaire related to the reasons for visiting the open spaces, frequency of use, length of time and time range. The fourth part related to thermal sensation. The question regarding prior thermal history was intended to understand the subjects' immediate thermal experiences. The question of overall thermal sensation was adapted to the ASHRAE 55-2010 standard using a 7-point scale (-3 to 3). A 6-point scale was used for thermal comfort and thermal acceptability from -3 to 3. The last part of the questionnaire concerned the elderly's overall satisfaction with the provided open spaces.

The surveys were conducted during winter from December 2016 to February 2017 and summer in June 2017. The surveys were completed in 9 days in the winter months and 6 days in the summer between the hours of 07:00am and 16:00pm. One researcher and several student helpers were involved. Appendix A shows the exact dates, time and weather conditions during the study days.

4.3 Site selection

The study incorporated six different outdoor open spaces in two districts in Hong Kong. Two were podium gardens within the elderly's housing projects and four were public parks within a five minute walk from the elderly's housing projects. Originally, three of the housing projects, managed by the Hong Kong Housing Society, were chosen as study sites. However, due to the strict security regulations of the Tanner Hill project in North Point, only two projects, Cheerful Court in Kwun Tong and Jolly Place in Tseung Kwan O, were finally investigated. After site visits to the elderly, it was found that very few of them use the podium gardens in the mornings and afternoons. As a result, two public parks in each respective district within a five minute walk from the elderly's housing were selected for investigation. We intended to obtain responses from the elderly who also live or stay in the vicinity of their housing. Appendix B is a summary of the features and amenities provided in the study parks. Appendix C also includes the layout plans showing park composition and the spatial layout of the study parks.

4.4 Characteristics of respondents

In this study, a total number of 454 questionnaires were collected: 235 in winter and 219 in summer. A combination of stratified and convenient sampling method was adopted to conduct the questionnaires. Respondents who were 65 and above and who used open spaces were invited to participate in the study. Table 2 shows the profiles of the respondents, the length of stay in the districts and the satisfaction level with using the open spaces in the winter and summer periods, respectively. Interestingly, it reveals that the majority of elderly who go to the parks are a relatively financially disadvantaged group with fewer alternatives for leisure choices (66.5% have monthly expenditures lower than $5000). The Hong Kong Census and previous studies show that the monthly expenditure of most elderly people in Hong Kong is between $1000-$5000 (Census and Statistics Department, 2013; Sun et al., 2010; Wong et al., 2018).

Table 3 shows the number of people who were surveyed in each park, their typical clothing level, activity level and position values in winter and summer.

Table 2: Profile of the respondents

	Full sample	Winter	Summer
Gender			
Female	247(54.4%)	114(48.5%)	133(60.7%)
Male	207(45.6%)	121(51.5%)	86(39.3%)
Age			
65-69	105(23.1%)	47(20.0%)	58(26.5%)
70-79	197(43.4%)	104(44.3%)	93(42.5%)
80-89	131(28.9%)	68(28.9%)	63(28.8%)
>=90	21(4.6%)	16(6.8%)	5(2.3%)
Education level			
Primary and below	265(58.3%)	129(54.9%)	136(62.1%)
Secondary	150(33.0%)	78(33.2%)	72(32.9%)
Post-secondary	39(8.6%)	28(11.9%)	11(5.0%)
Monthly expenditure			
<$3000	110(24.2%)	64(27.2%)	46(21.0%)
$3000-4999	192(42.3%)	82(34.9%)	110 (50.2%)
>=$5000	152(33.5%)	89(37.9%)	63(28.8%)
Clothing Level			
Max	1.39	1.39	0.91
Mean	0.625	0.918	0.310
Min	0.21	0.47	0.21
Times visiting each week			
0-2 days	59(13.0%)	35(14.9%)	24(11.0%)
3-4 days	93(20.5%)	44(18.7%)	49(22.4%)
5-6 days	104(22.9%)	40(17.0%)	64(29.2%)
everyday	198(43.6%)	116(49.4%)	82(37.4%)
Satisfaction level			
Very dissatisfied	0(0%)	0(0%)	0(0%)
Dissatisfied	13(2.9%)	9(3.8%)	4(1.8%)

Neutral	93(20.5%)	52(22.1%)	41(18.7%)
Satisfied	290(63.9%)	138(58.7%)	152(69.4%)
Very satisfied	58(12.8%)	36(15.3%)	22(10.0%)

Table 3 Number of respondents, typical clothing level, activity level and position values in winter and summer.

		Cheerful Court		Choi Hei Road Park		Choi Ha Road Sitting-out Area		Jolly Place		PuiShing Garden		Hang Hau Man Kuk Lane Park	
Season		W	S	W	S	W	S	W	S	W	S	W	S
Number of elderly		29	24	33	41	54	49	18	18	62	42	39	45
Clo	Max	1.39	0.91	1.34	0.54	1.19	0.33	1.19	0.83	1.34	0.49	1.19	0.48
	Mean	1.098	0.373	0.905	0.29	0.886	0.296	0.771	0.362	0.912	0.306	0.916	0.292
	Min	0.59	0.23	0.49	0.21	0.47	0.21	0.49	0.23	0.49	0.25	0.49	0.23
Activity	Max	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.0
	Mean	2.255	2.379	2.245	1.985	1.894	2.257	1.228	1.444	1.929	2.545	2.037	2.007
	Min	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Position	Near Greenery	3 (10.34%)	1(4.17%)	11(33.33%)	0(0%)	26(48.15%)	1(2.04%)	15(83.33)	1(5.56%)	22(35.48%)	8(19.05%)	15(38.46%)	13(28.89%)
	Near Water	0(0%)	0(0%)	0(0%)	1(2.44%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	5(11.90%)	10(25.64%)	16(35.56%)
	Special play ground	11(37.93%)	3(12.5%)	6(18.18%)	7(17.07%)	14(25.93%)	6(12.24%)	1(5.56%)	6(33.33%)	19(30.65%)	8(19.05%)	6(15.38%)	6(13.33%)
	Others	15(51.72%)	20(83.33%)	16(48.48%)	33(80.49%)	14(25.93%)	42(85.71%)	2(11.11%)	11(61.11%)	21(33.87%)	21(50.00%)	8(20.51%)	10(22.22%)

4.6 Data processing and analysis

The mean radiant temperature (Tmrt) and a thermo physiological index called Physiologically Equivalent Temperature (PET) were calculated and analyzed in this study. The equation (1) can be used to calculate the Tmrt value (ASHRAE, 2009).

$$T_{mrt} = \left[\frac{(T_g+273)^4+(1.10*10^8 V^{0.6})(T_g-T_a)}{(\varepsilon D^{0.4})}\right]^{1/4} - 273 \qquad (1)$$

Where T_{mrt} is mean radiant temperature (°C), T_g is globe temperature (°C), T_a is air temperature (°C), V is air velocity (m/s), D is globe diameter (m) and ε is emissivity.

Physiologically Equivalent Temperature (PET) was applied as the thermal comfort index in this study because 1) it is an accurate thermal index for outdoor thermal comfort and is widely used around the world (Matzarakis & Mayer, 1996; Ng & Cheng, 2012), thus, it is easy to compare the results of our study with other studies; 2) it is officially used by the German Meteorological Service and recommended by German engineering guidelines VDI 3787 (2008) for human biometeorology evaluation of climate in physical planning (Ng & Cheng, 2012; Li et al., 2016); 3) PET is relatively easier to compute using free software compared to other thermal indices.

Meteorological parameters, including air temperature, relative humidity and wind speed were used for calculation of PET (Höppe, 1999; Lin, 2009). The PET value was calculated by using RayMan software. Air temperature, relative humidity, wind velocity and global radiation were input, while clothing (clo=0.9) and activity (metabolic rate=80w) were assumed constant (Matzarakis et al., 1999; Li et al., 2016). The detailed methodology and parameters employed in the PET model have been described in aprevious study (Matzarakis, Rutzand & Mayer, 2010).

Based on the data collected from the on-site measurements and questionnaire surveys, a series of analyses were carried out. Firstly, the ordered probit model (equation 2) was used to estimate how the predictor variables (physical, individual and social factors) could impact the response variable (thermal perception, overall satisfaction level and length of stay in the open spaces).

$$\ln\left[\frac{P(Y \leq j)}{1 - P(Y \leq j)}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m \quad (2)$$

This method is suitable for a thermal comfort study, where the dependent variable is an ordinal variable, and has been shown to provide the same results as other conventional analytical tests (Humphreys, Nicol & Roaf, 2015). The McFadden Pseudo r-square was applied to test the strength of the relationship between response and predictor variables.

Secondly, the binary logistics regression model (equation 3) was used to investigate the key factors that impact people's choice of whether or not to stay in shaded areas. With the Hosmer and Lemeshow Test, we evaluated the goodness of fit, while the overall percentage was used to evaluate the percentage of correct prediction of the model. SPSS Statistics 23 (International Business Machines Corp., New York, United States) software was employed in this study to analyze the data, run the regression models and plot the results.

$$Logit\ (P) = \ln\frac{P(Y = 1)}{P(Y = 0)} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m \quad (3)$$

Where $P(Y \leq j)$ or $P(Y = 1)$ is the probability of the event, β_0 is the constant, (0 represents non-shaded areas, 1 represents shaded areas) Y is the response variable, x_m is the predictor variable, β_m is the coefficient of the predictor variable. The larger coefficients (β) indicate an association with larger scores (Y), positive coefficient means higher scores of Y are more likely compared to the reference category and the negative coefficient shows that lower scores of Y are more likely.

5. Results and discussions

5.1. Influential factors on the elderly's thermal perceptions

The results of ordered probit model for elderly thermal perceptions are shown in Tables 4 and 5.

5.1.1 Effects of physical factors

With the winter model, clothing level and PET were shown to be associated with the elderly's thermal comfort and thermal sensation, respectively. The results of the regression analysis indicated that clothing insulation has a negative impact on the elderly's thermal comfort (estimate=-1.082, $p<0.05$). This means that the larger the clothing insulation value, the more likely the elderly feel less thermally comfortable during the winter in Hong Kong. This finding is different from other studies which looked at all age groups (Wilson et al., 2008). This raises the point that while the elderly may feel warmer wearing more clothes in the winter, it does not necessarily mean that they are feeling thermally comfortable.

The results also show that PET has a positive relationship with the elderly's thermal sensation (estimate=0.071, $p<0.01$). With the increase of PET value, elderly people in Hong Kong are more likely to feel warm or hot. Previous research found that activity level is an important factor of people's thermal comfort. However, the current study shows no significant relationship between activity level and the elderly's thermal perception in winter and in summer. This could be due to the fact that doing exercise is a regular activity for many elderly people throughout the year and, therefore, activity level does not have a significant effect on the elderly's thermal perception in winter or summer.

5.1.2. Effects of individual factors

In previous research, individual differences, such as age, gender, skin colour, health status, influence people's thermal comfort and acceptability were taken into consideration. With the winter model, the results indicate that individual factors have a notable impact on the elderly's thermal comfort, sensation and acceptability.

In contrast, the summer model showed that educational background has a positive impact on the elderly's thermal sensation vote (estimate=0.375, $p<0.01$). This indicates that the elderly who have higher educational backgrounds are more likely to have higher thermal sensation votes, such as 'warm' or 'hot' in the summer. In other words, level of education may change the elderly's thermal preferences and expectations and, hence, increase their minimum requirements for thermal comfort (Frontczak &

Wargocki, 2011). Our results are also in line with the findings of Aljawabra and Nikolopoulou (2010).

The effect of age is also significant during the summer and has a negative impact on the elderly's thermal comfort (estimate=-0.221, $p<0.05$). With the increase of age, elderly people are more likely to feel less thermally comfortable during the summer in Hong Kong. Knez et al. (2009) explain that age can be seen as a kind of attitude, and age-related experiences affect people's expectations towards the thermal environment in open spaces. People may have different requirements and expectations of thermal conditions at different stages, so the implication is that the elderly require a higher level of thermal comfort in the summer months.

In addition, gender is also highly associated with levels of thermal sensation and thermal acceptability. The female elderly are more likely to give higher thermal sensation votes (estimate=0.627, $p<0.01$) during the summer and also have a higher possibility of feeling less thermally acceptable (estimate=-0.470, $p<0.01$) than the male elderly. This is quite similar to the previous findings of Kruger and Rossi (2011). In Huang et al.'s (2016) study, which includes a young age group in Wuhan, it was also found that males prefer warmer climates than females. This indicates that the female population as a whole is less tolerant of heat stress than males.

5.1.3. Effects of social/psychological factors

Social/psychological factors were examined using three sub-factors: reason to visit open spaces, companionship and thermal history. Some of the sub-factors were found to have an impact on the elderly's thermal comfort/sensation/acceptability in both summer and winter, respectively. However, the effects during the different seasons vary.

The winter model showed that thermal reasons are the most important factors, having significant impact on all three response variables (Table 4). The results show that the elderly who visit open spaces because of enjoyment obtained from being in shaded areas, sunlight, wind and fresh air have a higher likelihood of indicating a lower level of thermal comfort (estimate=-0.422, $p<0.05$), higher thermal sensation vote (estimate=0.466, $p<0.01$) and lower level of thermal acceptability (estimate=-0.461, $p<0.05$) than those who visit for other reasons. The other four reasons were not found to be significantly associated with the elderly's thermal perceptions. Companionship and thermal history also showed no significant effect on the elderly's thermal perception in the winter.

The summer model indicated that the elderly visit open spaces for social reasons, such as meeting friends. Therefore, social networking is more likely to have a higher level of thermal acceptability (estimate=0.674, $p<0.05$). In addition, the elderly who visit open spaces for physical reasons, such as doing exercise, participating in activities and improving health, are more likely to indicate a higher level of thermal comfort (estimate=0.410, $p<0.05$) or higher thermal acceptability (estimate=0.410, $p<0.05$) than other elderly people. Furthermore, thermal history influences the elderly's thermal sensation in the summer. The elderly who visited indoor air-conditioned spaces 15 minutes prior to the survey were more likely to have a higher thermal sensation vote (estimate=0.441, $p<0.05$) during that season. The results show no significant relationship between companionship and the elderly's thermal perception in the summer, which is different from previous studies (Table 5).

Similar to previous studies, this study found that social and psychological factors have an impact on the elderly's thermal perception (Nikolopoulou & Steemers, 2003; Lin, 2009; Cohen et al., 2013). The reason to visit open spaces has a significant effect on the elderly's thermal perception. This can be explained in that the elderly have different requirements and expectations of thermal conditions. When the elderly visit open spaces for social reasons, they are more likely to indicate a higher level of thermal acceptability during the summer, because the thermal conditions are not their main reason for being there. Therefore, they have fewer requirements and lower expectations of thermal environments in open spaces. When compared with other demographic groups, Lin (2009) indicated that in Taichung, psychological factors, such as experience and expectation, play a very important role in all age groups' outdoor thermal comfort.

The effect of thermal history is also in line with the study conducted by Nikolopoulou, Baker and Steemers (2001) who showed that thermal history is a kind of psychological adaptation. The results from the summer month clearly show that thermal history is an important factor that affects people's thermal sensations in outdoor open spaces.

Table 4: Results of probit model regression estimates (in winter)

	Model 1: Thermal Comfort		Model 2: Thermal Sensation		Model 3: Thermal Acceptability	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Physical factors						

PET	.018	.347	**.071**	**.000****	.014	.484
Clothing	**-1.082**	**.019***	-.120	.759	-.626	.192
Activity	-.105	.261	-.144	.072	-.154	.130
Individual factors						
Age	-.079	.483	.068	.487	.124	.298
Education	.016	.881	.008	.930	.019	.872
Monthly expenditure	-.065	.271	-.045	.376	-.013	.832
Gender						
Female	.108	.610	.121	.512	-.154	.499
Male	0	.	0	.	0	.
Social/Psychological factors						
Reason to visit open spaces						
Reason 1: Social (Social network, appointment, habit)	-.110	.617	.200	.304	-.182	.438
Reason 2: Physical (doing exercise, health condition, activity)	.026	.891	.103	.527	.061	.757
Reason 3: Spatial (live nearby, passing by)	-.125	.544	.160	.373	.106	.625
Reason 4: Design (design of park, facilities, greenery)	-.268	.230	.044	.818	.315	.172
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	**-.422**	**.029***	**.466**	**.005****	**-.461**	**.024***
Companionship	.105	.649	-.153	.449	.225	.353
Thermal History	.510	.061	.134	.589	.448	.112
Goodness of Fit	1.000		1.000		1.000	
McFadden Pseudo r-square	.091		.094		.085	

* Significant at the 0.05 level (2-tailed) **Significant at the 0.01 level (2-tailed).

Notes: r^2=0.01 means small effect, r^2=0.09 means medium effect, and r^2=0.25 means large effect (Gravetter & Wallnau, 2010).

Table 5: Results of probit model regression estimates (in summer)

	Model 1: Thermal Comfort		Model 2: Thermal Sensation		Model 3: Thermal Acceptability	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Physical factors						
PET	-.002	.945	-.014	.618	-.024	.352
Clothing	-.014	.707	.373	.729	.029	.458
Activity	.047	.538	.007	.927	.008	.916
Individual factors						
Age	**-.221**	**.028***	.038	.721	.007	.942
Education	.013	.890	**.375**	**.000****	.100	.306
Monthly expenditure	-.044	.427	.095	.114	-.056	.327
Gender						
Female	-.281	.095	**.627**	**.000****	**-.470**	**.007****
Male	0	.				
Social/Psychological factors						
Reason to visit open						

space						
Reason 1: Social (Social network, appointment, habit)	.358	.267	-.280	.420	**.674**	**.043***
Reason 2: Physical (doing exercise, health condition, activity)	**.410**	**.025***	.008	.969	**.410**	**.029***
Reason 3: Spatial (live nearby, passing by)	.119	.461	-.229	.182	.091	.581
Reason 4: Design (design of park, facilities, greenery)	.030	.908	-.129	.635	.194	.472
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	.195	.296	-.262	.184	-.131	.490
Companionship	.076	.678	-.166	.400	.067	.718
Thermal History	-.066	.740	**.441**	**.043***	-.174	.390
Goodness of Fit	1.000		1.000		1.000	
McFadden Pseudo r-square	.033		.074		.042	

* Significant at the 0.05 level (2-tailed) **Significant at the 0.01 level (2-tailed).

Notes: r^2=0.01 means small effect, r^2=0.09 means medium effect, and r^2=0.25 means large effect (Gravetter & Wallnau, 2010).

5.2 The elderly's thermal perceptions and use patterns and satisfaction with open space

5.2.1 Overall satisfaction with using open space

Overall, the elderly's satisfaction with the use of open space was investigated and their relationship with the individual factors, physical factors and social/psychological factors in summer and winter were also examined (Table 6).

With the summer model, a significant relationship between the reasons for visiting open spaces (design aspect) and the elderly's overall satisfaction derived from using open spaces was shown. It was seen that design has a positive association (estimate=0.606, $p<0.05$) with elderly's overall satisfaction with open spaces during the summer. Compared to those who visit open spaces for other reasons, the elderly who go there for the facilities, greenery and other design features are more likely to indicate higher satisfaction.

Education was found to have a negative relationship (estimate=-0.205, $p<0.05$) with the elderly's overall satisfaction. The elderly who have higher educational backgrounds are more likely to feel less satisfaction with open spaces. The elderly who go to open spaces because of spatial reasons have a negative relationship (estimate=-0.503, $p<0.01$) with the elderly's overall satisfaction. This reveals that the elderly who visit open spaces because of proximity or because they are passing by have a higher possibility of indicating a lower level of satisfaction.

The results show that the reasons for visiting open spaces and educational background have an influence on the satisfaction the elderly derive from using open spaces. People who have higher educational backgrounds may have higher standards of requirements and expectations, so they are more likely to indicate a lower satisfaction level. Elderly people who go to open spaces because of their design may have increased satisfaction. For the elderly who visit open spaces for spatial reasons, they primarily go there to enjoy the environment rather than to participate in activities or social interactions.

Table 6: Results of probit model regression estimates for satisfaction level and length of stay in open spaces

	Model 1: Satisfaction (Summer)		Model 2: Satisfaction (Winter)		Model 3: Length of stay in open spaces	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Individual						
Age	-.073	.513	-.036	.707	**-.216**	**.037***
Education	.171	.124	**-.205**	**.023***	-.132	.198
Monthly expenditure	.111	.072	.033	.495	**.116**	**.048***
Gender						

Female	.236	.214	-.022	.901	.102	.566
Male	0	.	0	.	0	.
Social/Psychological factors						
Reason to visit open spaces						
Reason 1: Social (Social network, appointment, habit)	-.354	.320	-.143	.441	.288	.381
Reason 2: Physical (doing exercise, health condition, activity)	.033	.873	.065	.675	-.090	.637
Reason 3: Spatial (live nearby, passing by)	.030	.866	**-.503**	**.004****	-.088	.595
Reason 4: Design (design of park, facilities, greenery)	**.606**	**.040***	.090	.629	.186	.489
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	.217	.289	.214	.190	-.242	.209
Companionship	.126	.530	.360	.070	**.692**	**.000****
Thermal history	.010	.963	-	-	-.394	.056
Physical factors						
PET	-.013	.640	.017	.299	.023	.371
Clothing	-.020	.629	.099	.795	-1.974	.059
Activity	.128	.128	.141	.069	.084	.278
Thermal Perception						
Thermal Comfort	-.103	.222	-.192	.175	-.129	.100
Thermal Sensation	-.032	.666	-.020	.858	-.110	.113
Thermal acceptability	**.239**	**.005****	**.775**	**.000****	**.174**	**.027***
Goodness of Fit	1.000		1.000		1.000	
McFadden Pseudo r-square	.078		.081		.097	

* Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed).

Notes: r^2=0.01 means small effect, r^2=0.09 means medium effect, and r^2=0.25 means large effect (Gravetter & Wallnau, 2010).

The empirical results show that thermal acceptability has a positive association with the elderly's overall satisfaction with using open spaces in both summer (estimate=0.239, p<0.01) and winter (estimate=0.775, p<0.01) (Table 6). Elderly people who vote a higher thermal acceptability level are more likely to experience higher satisfaction with using open spaces. Therefore, thermal acceptability is an important factor influencing the elderly's satisfaction with open spaces.

5.2.2 Use patterns - length of time the elderly stay in open spaces

The length of time the elderly stay in open spaces is an important aspect reflecting their use patterns. Table 6 shows the results. The study only examined the lengths of stay during the summer. This can be justified and supported by the elderly's indication that the thermal environment in the summer in Hong Kong is consistently hot and uncomfortable, whereas the thermal environment is neutral and comfortable in the winter. Thus, it would be unlikely that thermal environmental conditions would be related to length of stay in the winter.

The study by Cheung and Jim (2018), which mainly examined young adults and children (only 1.9% of people were over 64), indicated that enhancing thermal comfort and extending usable time can increase attendance of open spaces. In this present study, the amount of time the elderly stay in open spaces is affected by age, monthly expenditure, companionship and thermal acceptability in the summer model. It is indicated that age has a negative impact (estimate=-0.216, $p<0.05$) on people's staying time. With the increase of age, the elderly are more likely to spend shorter periods of time in open spaces in the summer. The effect of age can be explained by the fact that older people are often in poorer health and may not have enough energy to spend too much time doing activities in open spaces, thus, their use patterns change.

Companionship is found to exert a positive effect (estimate=0.692, $p<0.01$) on the elderly's stay in open spaces. Compared to the elderly who go to open spaces by themselves, those who visit or use open spaces to meet friends and families have a higher possibility of staying for longer periods of time. This is because socializing with other people can possibly modify the elderly's use patterns and time spent in open spaces. The elderly who are alone may quickly lose interest in their surroundings.

Furthermore, the results (estimate=0.174, $p<0.05$) indicate that the elderly who vote a higher thermal acceptability level are more likely to stay longer in open spaces in the summer months.

5.2.3 Use patterns – the elderly's preference for being in shaded areas

The elderly's use patterns of open spaces include their preference for shaded areas. We included the variables thermal comfort, sensation and acceptability, physical factor and gender into the estimated equation. Table 7 reveals the binary logistic coefficient for each tested predictor variable for the response variable of whether the respondents are in shaded areas in the summer and winter months. With the winter model, it was revealed that activity has significant negative influence (estimate=-0.953, $p<0.01$) on the elderly's choice of whether to stay in shaded areas. With the increase of activity level, the elderly have less probability of staying in shaded areas. In addition, there is a higher possibility of elderly who visit open spaces because of social factors staying in shaded areas (estimate=0.822, $p<0.05$).

Using the summer model, it becomes apparent that activity level has a negative effect (estimate=-0.513, $p<0.01$) on the elderly's choice to stay in shaded areas. In addition, thermal comfort and gender are also found to be significant in influencing the elderly's decision to stay in shaded areas. It is shown that thermal comfort exerts a negative effect (estimate=-0.330, $p<0.05$) on the elderly's choices. The elderly who vote a higher thermal comfort level are less likely to stay in shaded areas. Furthermore, companionship is found to have a positive impact (estimate=0.860, $p<0.05$) on the elderly's choices. The elderly who visit open spaces with friends tend to have a higher probability of staying in shaded areas in the summer. It is also apparent that the female elderly have a higher probability (estimate=1.395, $p<0.01$) of staying in shaded areas than the male elderly during the summer months. It is widely recognized that females are more aware of the damage caused by sun radiation to the skin.

The results illustrate that the elderly's choices of open spaces are mainly influenced by their activity levels or types of activity in the winter, whereas, in the summer, thermal comfort and gender are also significant. The majority of the elderly prefers to stay in shaded areas when sitting or standing and move to non-shaded areas when doing heavy activities, which is quite similar to the findings of Martinelli et al. (2015). The social issue is also an important factor that affects the elderly's choice of location. The results show that the elderly who go to open spaces to meet friends or for social interaction are likely to stay in shaded areas in the winter. It is also shown that when thermal comfort conditions change, the elderly will try to adjust the thermal environment by changing their locations within the open spaces, as supported by Thorsson, Lindqvist and Lindqvist's (2004) study.

Table 7: Results of the binary logistic regression model for whether elderly prefer to stay in shaded areas

	Model 1: Whether in shade (summer)		Model 2: Whether in shade (winter)	
	estimate	Sig	estimate	Sig
Individual factors				
Age	.102	.618	.226	.246

Education	.214	.306	.287	.137
Monthly expenditure	-.017	.886	.181	.082
Gender				
Female	**1.395**	**.000****	.100	.786
Male	0	.	0	.
Social/Psychological factors				
Reason to visit open spaces				
Reason 1: Social (Social network, appointment, habit)	-.995	.131	**.822**	**.028***
Reason 2: Physical (doing exercise, health condition, activity)	-.085	.826	-.419	.187
Reason 3: Spatial (live nearby, passing by)	.163	.625	-.031	.929
Reason 4: Design (design of park, facilities, greenery)	.248	.653	-.157	.685
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	.145	.711	-.355	.292
Companionship	**.860**	**.028***	-.333	.413
Thermal history	.655	.124	-	-
Physical factors				
PET	.006	.907	-.051	.135
Clothing	.043	.840	-.105	.895
Activity	**-.513**	**.001****	**-.953**	**.000****
Thermal Perception				
Thermal Comfort	**-.330**	**.041***	.016	.957
Thermal Sensation	-.196	.160	.190	.425
Thermal acceptability	.243	.124	.328	.351
Hosmer and Lemeshow Test (Sig)	.698		.088	
Overall percentage (%)	68.0		71.5	

* Significant at the 0.05 level (2-tailed), **Significant at the 0.01 level (2-tailed).

5.4 External validity

According to the Census and Statistics Department (2011) in Hong Kong, the proportion of elderly people (aged 65 or above) is 16.3% (Kwun Tong) and 9.1% (Tseung Kwan O). Because of manpower constraints, the obtained valid questionnaires in the winter and summer were 235 (0.16%) and 219 (0.17%) of the entire elderly population of the two districts, respectively. According to Bartlett, Kotrlik and Higgins (2001), an appropriate sample size for a categorical data model is 264.The number of questionnaires obtained was slightly less than suggested, but our sample size is reasonably valid. Although the parks studied are not completely homogeneous in the physical factors, there are key features which have a cooling effect that are very similar among the study parks. In addition, the climate datam measured from the climate stations in Tseung Kwan O and Kwun Tong, also show that there is no apparent systematic bias of reported PETs towards a park space with a particular configuration or composition of vegetation. Thus, the likelihood of type II errors (false-negative) are decreased.

5.5 Urban planning and design implications

Our findings identified some important factors that are associated with the elderly's thermal perceptions, use patterns and satisfaction derived from using open spaces. They provided some valuable insights for urban planners, architects and urban designers regarding spatial planning and design layout of outdoor open spaces which can enhance the experiences of the users. Appropriate microclimatic planning and design considerations can mitigate negative aspects, therefore, increasing the use of outdoor space in different seasons.

This study shows that the reason behind visiting open spaces is an important aspect which is related to the elderly's thermal perception of the outdoor environment and the use patterns. The elderly who visit open spaces for different reasons may have different expectations of the thermal environment, so it is recommended that diverse microclimate conditions are provided so that they can adjust to different thermal conditions in different spaces in order to meet their preferences and expectations. As suggested by previous studies that looked at the provision of different kinds of environmental stimulation, people have a high tolerance for extreme conditions, unless exposure to discomfort is threatening (Nikolopoulou & Steemers, 2003). To cater for the special needs of the elderly who go to parks for thermal reasons, it is suggested that planning and design should provide diverse thermal conditions by incorporating a variety of sub-spaces within the parks. This would allow the elderly to enjoy shade, sunshine, exposure to breezes or protection from winds in different areas within the same space. In particular, given the global warming phenomenon, planners need to consider more carefully the micro-climate of the broader surrounding environment when locating the parks in order to mitigate heat stress in the outdoor environment. For consideration of the elderly who come to parks for physical reasons, age-friendly exercise facilities and amenities that are suitable for their elderly should be provided.

Social reasons and companionship were found to have significant influence on the elderly’s length of stay and use patterns in open spaces. Providing suitable open spaces can increase the elderly’s communication and interaction and, subsequently, improve their thermal perceptions and their length of time spent in open spaces, and vice versa. In addition, thermal history has an impact on the elderly’s thermal sensations in the summer. Although thermal history is not a psychological factor but rather a site-related factor, planners should still take this into consideration in the planning and design of open spaces. For instance, it could be useful to provide transitional areas between the indoors and the outdoors, such as corridors, covered walkways or arcades, and tree canopies so that the elderly can adjust to changing thermal conditions before entering into the open spaces. The difference between indoor or outdoor environmental conditions, especially heat stress, could be reduced by modifying the ground surfaces and planting more greenery.

Activity level has an influence on the elderly's choice of whether to stay in shaded areas. Regarding this point, it is suggested that seating should be provided for the elderly who undertake different kinds of light activities in shaded areas and open non-shaded areas should be available for dancing and other group exercises, like Tai Chi. Different ways to provide shading areas include building shelters with overhangs or vertical fins, tree canopies and planting greenery (Huang et al., 2016).

6. Conclusion

This study builds a conceptual framework for evaluating and providing a better understanding of the effect of the influencing factors on the elderly's thermal perceptions, and it also investigates whether and to what extent they are associated with the use patterns and satisfaction with open space.

Regarding the physical factors, PET and clothing were found to relate to the elderly's thermal perceptions (thermal sensation and thermal comfort) in the winter, but not in the summer. Since there is no association between thermal comfort, thermal sensation and satisfaction with using open space, it can be concluded that PET and clothing level has no influence on the elderly's satisfaction with using open space. Interestingly, results indicate that activity level has a direct influence on the elderly's use pattern in terms of their choice of staying in the shade during the winter and in the summer, while their impact on thermal perceptions was not significant.

For the individual factors, age, education level and gender were found to have a direct impact on the three measures of thermal perceptions in the summer, but not in the winter. However, there is no significant association between the individual factor and the satisfaction level and use patterns of open space.

In the case of the social/psychological factors, the variable, the elderly visit open spaces for thermal reasons, is the key element that influences thermal comfort, thermal sensation and acceptability during both the winter and summer months. It was found that thermal acceptability has a direct impact on the elderly's satisfaction with open spaces in both the winter and summer. As such, it can be deduced that the elderly who visit open spaces to enjoy the shade, sunlight and fresh breezes are more likely to have a higher requirement of level of thermal acceptability and this will also affect level of satisfaction with using open spaces. Thus, it is vitally important to improve the thermal environment in order to increase the elderly's satisfaction levels. The variable, companionship, was found to exert an influence on length of stay in open spaces during the summer, however, there was no significant relationship between companionship and the elderly's thermal perceptions or satisfaction level.

This study makes contributions to both the theory and practice of open space planning and design. It has developed a model which shows that elderly's sense of thermal acceptability is a mediator between the physical, individual and social psychological factors and their satisfaction with using open space. This study can enhance urban planners' understanding of the associated factors and requirements of the elderly's thermal perceptions, use patterns and use of open space. It is stressed that mere provision of physical facilities and consideration of design layout of outdoor spaces is not sufficient. The thermal comfort of the elderly is also important in enhancing their satisfaction with using the spaces.

The empirical results of this study provide a better understanding of the differences between thermal perceptions of the elderly and use patterns of parks in summers and winters. Given that the weather conditions are quite temperate in Hong Kong, (winter temperatures are normally around 14-16 °C and relative humidity is around 30%)) more attention should be paid to tackle summer heat stress. With the trend of global warming, increasing air temperatures could change people's use patterns of outdoor space, particularly in urban cities which has humid subtropical weather conditions in summer months. Therefore, a number of recommendations to meet the special needs of the elderly during the hot weather in summers are provided.

Firstly, the results indicate that 'come to the open space for its design' is a significant factor related to elderly's satisfaction with using the parks in summer. Thus, it is important to provide a variety of facilities and greenery types to improve the design quality of parks. Secondly, it is shown that 'companionship' is a significant factor related to length of stay in open spaces in the summer, thus providing activity spaces for the elderly's social interactions could increase their length of stay in open spaces. Thirdly, thermal acceptability is a significant factor related to both satisfaction and length of stay in open spaces in the summer, thus providing an acceptable thermal environment in open space is essential. Fourthly, 'come to the open space for social reasons' and ''come to the open space for physical reasons' are two significant factors related to the elderly's thermal acceptability in the summer, thus providing more space for social activities and more fitness facilities that could help to improve elderly's thermal acceptability in the summer.

Although mitigating summer heat stress should be considered to be more important than winter cold stress, flexible designs and spatial arrangements should be incorporated into the planning of public open spaces. It is suggested that design should provide diversity of thermal environment, e.g., spaces with different levels of shading, such as pergolas, cantilevers, verandahs and even flexible shading devices. In addition, devices generating cooling mist can be installed to reduce air temperature, particularly in areas with exposure to the sun's radiation. Moreover, location of activity spaces could be altered in summer and winter. Furthermore, a variety of transition areas, such as outdoor open spaces, semi-outdoor open spaces and indoor spaces could be incorporated in the park designs to mitigate the temperature difference between cool indoor air-conditioned spaces and hot outdoor spaces.

In a broader planning context, the planner should consider more carefully the micro-climate of the surrounding environment for park location, as well as the internal layout and provision of the different facilities in order to mitigate heat stress. Comprehending the wide range of factors influencing the elderly's thermal comfort in outdoor spaces will assist in the design of a variety of spaces encouraging more inclusive public use throughout the year.

However, due to limited human resources, only a small sample of open space was involved in this study, which could be seen as a limitation. In addition, the sample size mainly represented the elderly living in or near elderly housing estates. Given the difficulties in conducting well-replicated and experimental research examining thermal aspects, it is important to draw results across different studies to enable more general conclusions to be made, rather than relying on limited numbers of outdoor open spaces. Further study could include investigations of more open spaces and a larger sample of respondents to provide a better understanding of landscape design, size of parks, geographical and spatial differences that are associated with the elderly’s thermal perception, use patterns and satisfaction with open spaces.

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Table 7 PET and Garde of physiological stress, according to Lin and Matzarakis, 2008

PET	Garde of physiological stress	Winter		Summer	
		Percentage (%)	Cumulative percentage (%)	Percentage (%)	Cumulative percentage (%)
<14	Extreme cold stress	23.0	23.0	---	---
14-18	Strong cold tress	35.3	58.3	---	---
18-22	Moderate cold stress	24.3	82.6	---	---
22-26	Slight cold stress	9.8	92.3	.5	.5
26-30	No thermal stress	3.4	95.7	21.0	21.5
30-34	Slight heat stress	1.7	97.4	57.5	79.0
34-38	Moderate heat stress	1.7	99.1	14.2	93.2
38-42	Strong heat stress	.9	100.0	5.9	99.1
>42	Extreme heat stress	---	---	.9	100.0

Table 2: Profile of the respondents

	Full sample	Winter	Summer
Gender			
Female	247(54.4%)	114(48.5%)	133(60.7%)
Male	207(45.6%)	121(51.5%)	86(39.3%)
Age			
65-69	105(23.1%)	47(20.0%)	58(26.5%)
70-79	197(43.4%)	104(44.3%)	93(42.5%)
80-89	131(28.9%)	68(28.9%)	63(28.8%)
>=90	21(4.6%)	16(6.8%)	5(2.3%)
Education level			
Primary and below	265(58.3%)	129(54.9%)	136(62.1%)
Secondary	150(33.0%)	78(33.2%)	72(32.9%)
Post-secondary	39(8.6%)	28(11.9%)	11(5.0%)
Monthly expenditure			
<3000	110(24.2%)	64(27.2%)	46(21.0%)
3000-4999	192(42.3%)	82(34.9%)	110 (50.2%)
>=5000	152(33.5%)	89(37.9%)	63(28.8%)
Times to visit each week			
0-2 days	59(13.0%)	35(14.9%)	24(11.0%)
3-4 days	93(20.5%)	44(18.7%)	49(22.4%)
5-6 days	104(22.9%)	40(17.0%)	64(29.2%)
everyday	198(43.6%)	116(49.4%)	82(37.4%)
Satisfaction level			
Very dissatisfied	0(0%)	0(0%)	0(0%)
Dissatisfied	13(2.9%)	9(3.8%)	4(1.8%)
Neutral	93(20.5%)	52(22.1%)	41(18.7%)
Satisfied	290(63.9%)	138(58.7%)	152(69.4%)
Very satisfied	58(12.8%)	36(15.3%)	22(10.0%)

Table 3: number of respondents, typical clothing level, activity level and position values in winter and summer

		Cheerful Court		Choi Hei Road Park		Choi Ha Road Sitting-out Area		Jolly Place		PuiShing Garden		Hang Hau Man Kuk Lane Park	
Season		W	S	W	S	W	S	W	S	W	S	W	S
Number of elderly		29	24	33	41	54	49	18	18	62	42	39	45
Clo	Max	1.39	0.91	1.34	0.54	1.19	0.33	1.19	0.83	1.34	0.49	1.19	0.48
	Mean	1.098	0.373	0.905	0.29	0.886	0.296	0.771	0.362	0.912	0.306	0.916	0.292
	Min	0.59	0.23	0.49	0.21	0.47	0.21	0.49	0.23	0.49	0.25	0.49	0.23
Activity	Max	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.0
	Mean	2.255	2.379	2.245	1.985	1.894	2.257	1.228	1.444	1.929	2.545	2.037	2.007
	Min	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Position	Near Greenery	3 (10.34%)	1(4.17%)	11(33.33%)	0(0%)	26(48.15%)	1(2.04%)	15(83.33)	1(5.56%)	22(35.48%)	8(19.05%)	15(38.46%)	13(28.89%)
	Near Water	0(0%)	0(0%)	0(0%)	1(2.44%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	5(11.90%)	10(25.64%)	16(35.56%)
	Special playground	11(37.93%)	3(12.5%)	6(18.18%)	7(17.07%)	14(25.93%)	6(12.24%)	1(5.56%)	6(33.33%)	19(30.65%)	8(19.05%)	6(15.38%)	6(13.33%)
	Others	15(51.72%)	20(83.33%)	16(48.48%)	33(80.49%)	14(25.93%)	42(85.71%)	2(11.11%)	11(61.11%)	21(33.87%)	21(50.00%)	8(20.51%)	10(22.22%)

Table 4: Results of probit model regression estimates (in winter)

	Model 1: Thermal Comfort		Model 2: Thermal Sensation		Model 3: Thermal Acceptability	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Individual factors						
Age	-.079	.483	.068	.487	.124	.298
Education	.016	.881	.008	.930	.019	.872
Monthly expenditure	-.065	.271	-.045	.376	-.013	.832
Gender						
Female	.108	.610	.121	.512	-.154	.499
Male	0	.	0	.	0	.
Social/Psychological factors						
Reason to visit open spaces						
Reason 1: Social (Social network, appointment, habit)	-.110	.617	.200	.304	-.182	.438
Reason 2: Physical (doing exercise, health condition, activity)	.026	.891	.103	.527	.061	.757
Reason 3: Spatial (live nearby, passing by)	-.125	.544	.160	.373	.106	.625
Reason 4: Design (design of park, facilities, greenery)	-.268	.230	.044	.818	.315	.172
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	**-.422**	**.029***	**.466**	**.005****	**-.461**	**.024***
Companionship	.105	.649	-.153	.449	.225	.353
Thermal History	.510	.061	.134	.589	.448	.112
Physical factors						
PET	.018	.347	**.071**	**.000****	.014	.484
Clothing	**-1.082**	**.019***	-.120	.759	-.626	.192
Activity	-.105	.261	-.144	.072	-.154	.130
Goodness of Fit	1.000		1.000		1.000	
McFadden Pseudo r-square	.091		.094		.085	

Table 5: Results of probit model regression estimates (in summer)

	Model 1: Thermal Comfort		Model 2: Thermal Sensation		Model 3: Thermal Acceptability	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Individual factors						
Age	**-.221**	**.028***	.038	.721	.007	.942
Education	.013	.890	**.375**	**.000****	.100	.306
Monthly expenditure	-.044	.427	.095	.114	-.056	.327
Gender						
Female	-.281	.095	**.627**	**.000****	**-.470**	**.007****
Male	0	.				
Social/Psychological factors						
Reason to visit open space						
Reason 1: Social (Social network, appointment, habit)	.358	.267	-.280	.420	**.674**	**.043***
Reason 2: Physical (doing exercise, health condition, activity)	**.410**	**.025***	.008	.969	**.410**	**.029***
Reason 3: Spatial (live nearby, passing by)	.119	.461	-.229	.182	.091	.581
Reason 4: Design (design of park, facilities, greenery)	.030	.908	-.129	.635	.194	.472
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	.195	.296	-.262	.184	-.131	.490
Companionship	.076	.678	-.166	.400	.067	.718
Thermal History	-.066	.740	**.441**	**.043***	-.174	.390
Physical factors						
PET	-.002	.945	-.014	.618	-.024	.352
Clothing	-.014	.707	.373	.729	.029	.458
Activity	.047	.538	.007	.927	.008	.916
Goodness of Fit	1.000		1.000		1.000	
McFadden Pseudo r-square	.033		.074		.042	

Table 6: Results of probit model regression estimates for satisfaction level and length of stay in open spaces

	Model 1: Satisfaction (Summer)		Model 2: Satisfaction (Winter)		Model 3: Length of stay in open spaces	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Individual						
Age	-.073	.513	-.036	.707	**-.216**	**.037***
Education	.171	.124	**-.205**	**.023***	-.132	.198
Monthly expenditure	.111	.072	.033	.495	**.116**	**.048***
Gender						
Female	.236	.214	-.022	.901	.102	.566
Male	0	.	0	.	0	.
Social/Psychological factors						
Reason to visit open spaces						
Reason 1: Social (Social network, appointment, habit)	-.354	.320	-.143	.441	.288	.381
Reason 2: Physical (doing exercise, health condition, activity)	.033	.873	.065	.675	-.090	.637
Reason 3: Spatial (live nearby, passing by)	.030	.866	**-.503**	**.004****	-.088	.595
Reason 4: Design (design of park, facilities, greenery)	**.606**	**.040***	.090	.629	.186	.489
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	.217	.289	.214	.190	-.242	.209
Companionship	.126	.530	.360	.070	**.692**	**.000****
Thermal history	.010	.963	-	-	-.394	.056
Physical factors						
PET	-.013	.640	.017	.299	.023	.371
Clothing	-.020	.629	.099	.795	-1.974	.059
Activity	.128	.128	.141	.069	.084	.278
Thermal Perception						
Thermal Comfort	-.103	.222	-.192	.175	-.129	.100
Thermal Sensation	-.032	.666	-.020	.858	-.110	.113
Thermal acceptability	**.239**	**.005****	**.775**	**.000****	**.174**	**.027***
Goodness of Fit	1.000		1.000		1.000	
McFadden Pseudo r-square	.078		.081		.097	

Table 7: Results of the binary logistic regression model for whether elderly prefer to stay in shaded areas

	Model 1: Whether in shade (summer)		Model 2: Whether in shade (winter)	
	estimate	Sig	estimate	Sig
Individual factors				
Age	.102	.618	.226	.246
Education	.214	.306	.287	.137
Monthly expenditure	-.017	.886	.181	.082
Gender				
Female	**1.395**	**.000****	.100	.786
Male	0	.	0	.
Social/Psychological factors				
Reason to visit open spaces				
Reason 1: Social (Social network, appointment, habit)	-.995	.131	**.822**	**.028***
Reason 2: Physical (doing exercise, health condition, activity)	-.085	.826	-.419	.187
Reason 3: Spatial (live nearby, passing by)	.163	.625	-.031	.929
Reason 4: Design (design of park, facilities, greenery)	.248	.653	-.157	.685
Reason 5: Thermal (shading, sunlight, breezy, fresh air)	.145	.711	-.355	.292
Companionship	**.860**	**.028***	-.333	.413
Thermal history	.655	.124	-	-
Physical factors				
PET	.006	.907	-.051	.135
Clothing	.043	.840	-.105	.895
Activity	**-.513**	**.001****	**-.953**	**.000****
Thermal Perception				
Thermal Comfort	**-.330**	**.041***	.016	.957
Thermal Sensation	-.196	.160	.190	.425
Thermal acceptability	.243	.124	.328	.351
Hosmer and Lemeshow Test (Sig)	.698		.088	
Overall percentage (%)	68.0		71.5	

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Appendix A: exact dates, time and weather conditions during the study days

Appendix B: Major features and amenities provided in the study parks

Appendix C: The layout map and location of fixed weather station of study parks

Appendix A: exact dates, time and weather conditions during the study days

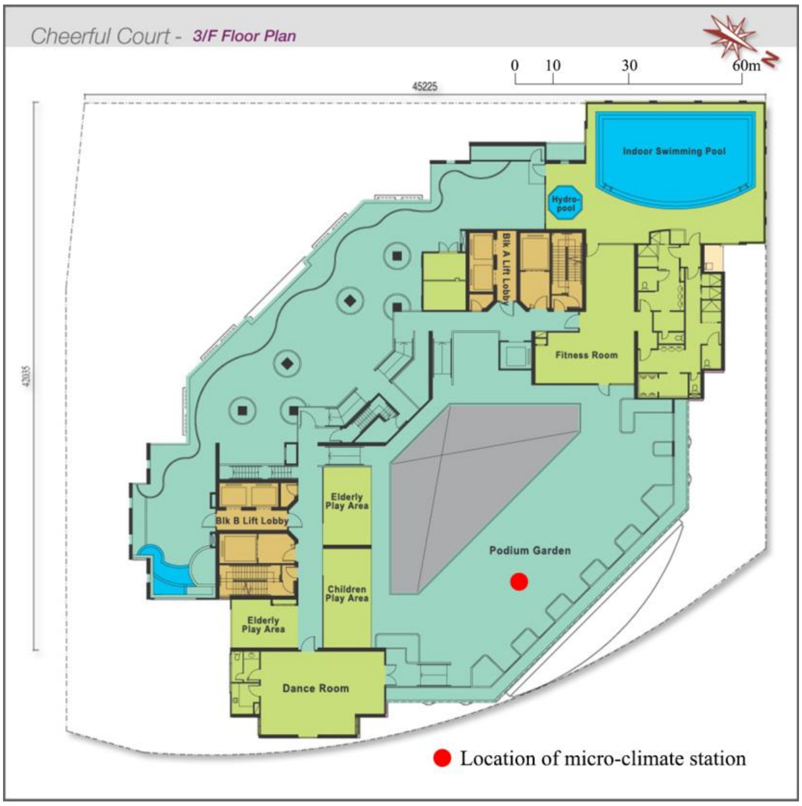
Date	Time	Mean weather conditions			Open Space
		Temp °C	Wind m/s	humidity	
2016/12/16	7:00-12:00	14.233	1.00	54.874	Cheerful Court
2016/12/16	14:00-17:00	17.322	0.39	50.473	Choi Ha Road Sitting-out Area
2016/12/20	7:00-12:00	21.233	0.61	80.020	PuiShing Garden
2016/12/22	14:00-17:00	24.312	0.66	57.813	Jolly Place
2016/12/23	7:00-16:00	20.660	0.84	66.068	Jolly Place
2016/12/28	7:00-16:00	13.785	0.28	56.277	Cheerful Court
2017/1/23	7:00-16:00	17.421	1.13	58.952	Choi Hei Road Park
2017/1/24	7:00-16:00	18.065	1.28	61.757	Choi Ha Road Sitting-out Area
2017/2/8	7:00-16:00	18.006	1.11	72.869	PuiShing Garden
2017/2/9	7:00-16:00	14.766	1.06	51.110	Hang Hau Man Kuk Lane Park
2017/6/23	7:00-16:00	30.438	0.45	77.742	Hang Hau Man Kuk Lane Park
2017/6/24	7:00-12:00	29.857	0.58	80.031	PuiShing Garden
2017/6/26	7:00-12:00	30.933	0.26	75.793	Choi Ha Road Sitting-out Area
2017/6/27	7:00-12:00	30.274	0.23	78.010	Choi Hei Road Park
2017/6/28	7:00-16:00	32.172	0.19	66.356	Jolly Place
2017/6/29	7:00-16:00	31.582	0.38	68.666	Cheerful Court

Appendix B: Major features and amenities provided in the study parks

Features/amenities	Cheerful Court	Choi Hei Road Park	Choi Ha Road Sitting-out Area	Jolly Place	Pui Shing Garden	Hang Hau Man Kuk Lane Park
Size (aprrox.)	0.08ha small	2.04ha large	0.45ha medium	0.09ha small	0.57ha medium	1.91ha large
Sitting area	√	√	√	√	√	√
Greenery (general type)	√ Trees and shrub.	√ Trees and shrub.	√ Trees and shrub.	√ Trees and shrub.	√ Trees and shrub.	√ Trees and shrub.
Natural sun-shading for activities	Fair	Fair	Good	Good	Fair	Good
built sun-shading structure	√	√	√	√	√	√
Pavilion/plaza for group gathering	√	×	√	×	√	√
Elderly Fitness Area	√	√	√	√	√	√
Sport field	×	×	×	×	×	√
Kiosk	×	√	√	×	√	√
Water features (pond, fountains)	×	×	×	√	×	√
Community Garden	×	×	×	×	×	×
Toilets	√	√	×	√	√	√
Thermal Comfort level (rank) (% of respondents indicating either comfortable or very comfortable)	67.9%	69.0%	**80.6%** **(1)**	61.1%	78.8% (2)	75% (3)
Thermal Acceptability level **(rank)** (% of respondents indicating either acceptable or very acceptable)	77.4%	78.4%	86.5% (3)	63.9%	88.4% (2)	91.7% (1)

Appendix C: The layout map and location of fixed weather station of study parks

Figure A1: Layout map of Cheerful Court



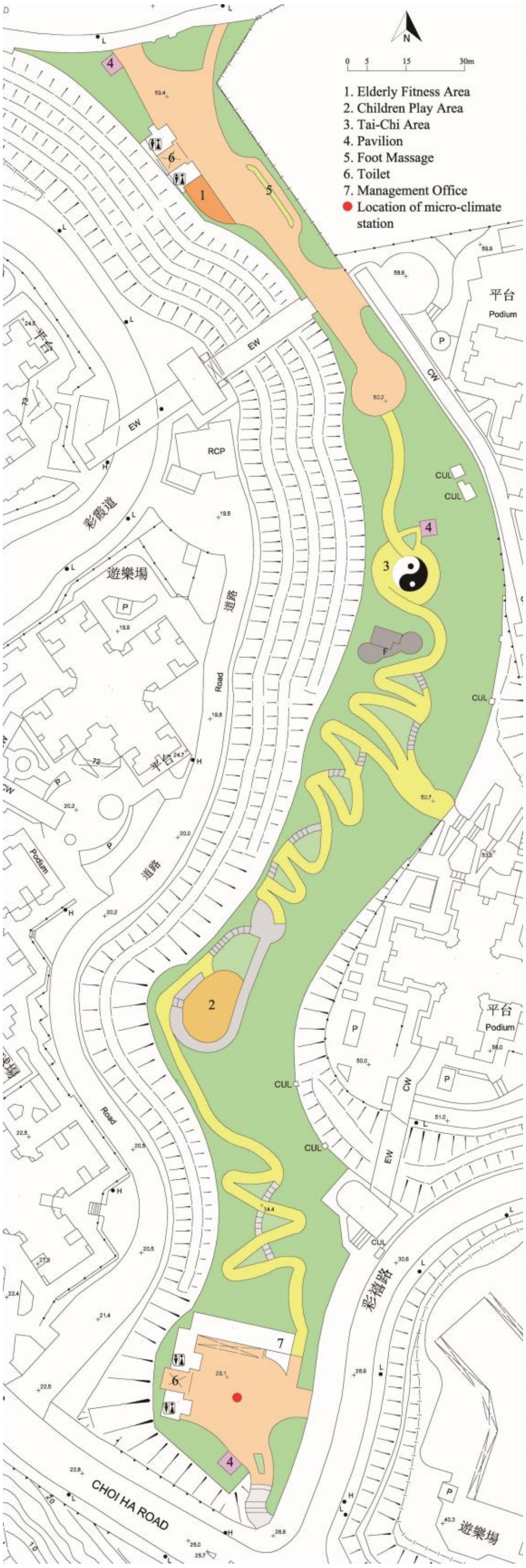
(Source: Hong Kong Housing Society)

http://www.hkhs.com/sen_20040903/eng/cheerful_court/maps/fp_tko_popup_3f.htm

Figure A2: Layout map of Choi Ha Road Sitting-out Area

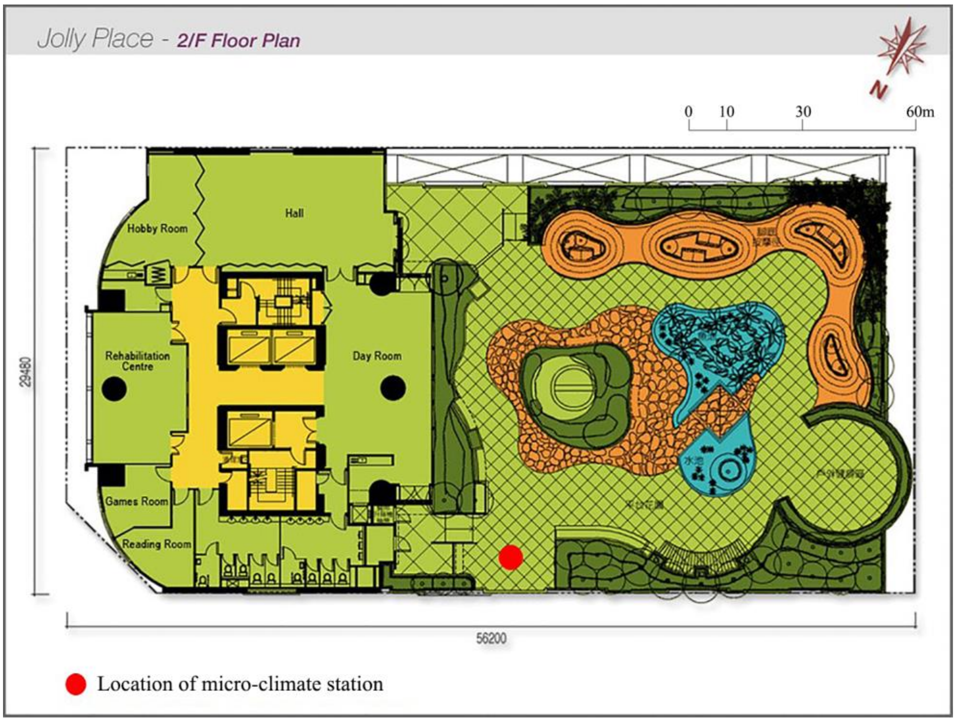
Source: drawn by authors

Figure A3: Layout map of Choi Hei Road Park



Source: drawn by authors

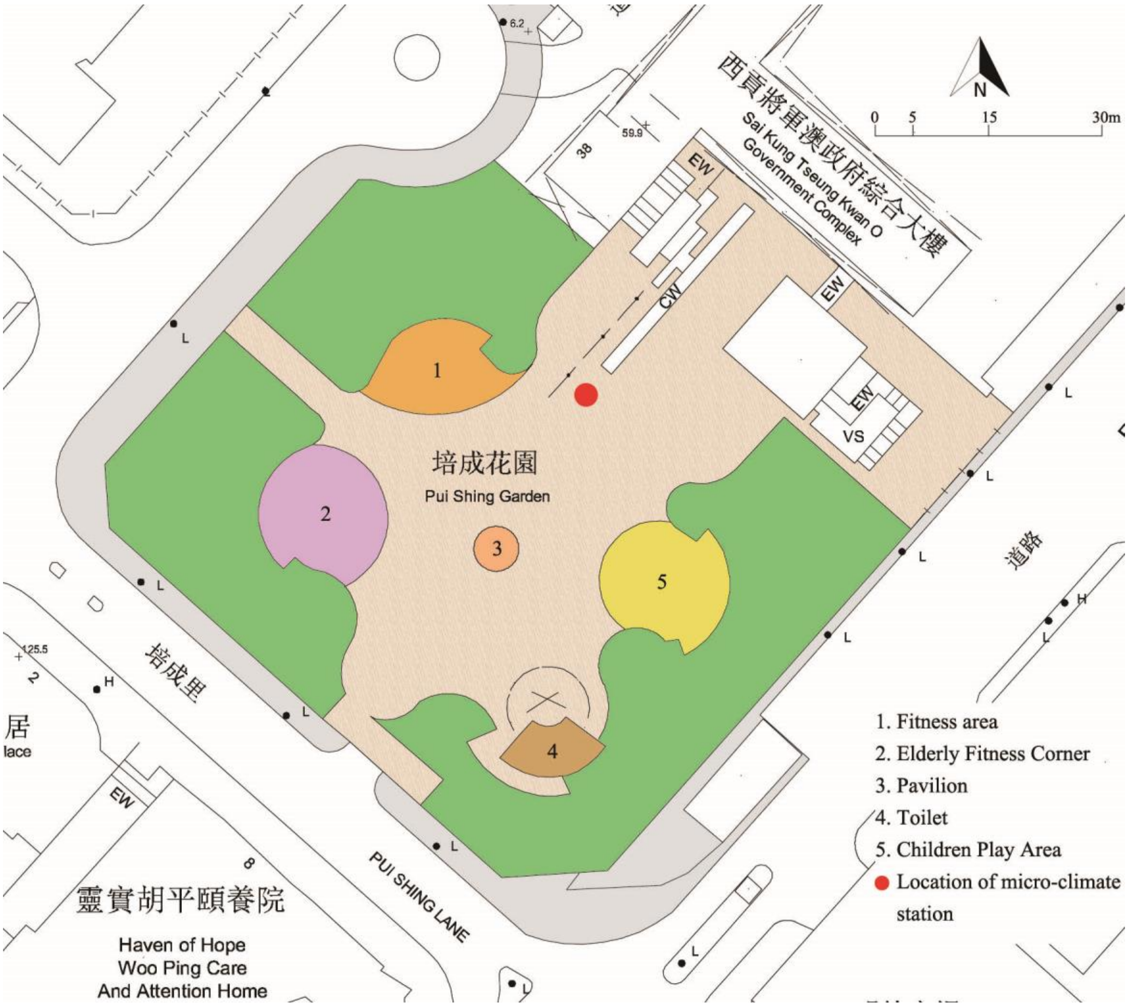
Figure A4: Layout map of Jolly Place



Source: Hong Kong Housing Society

http://www.hkhs.com/sen_20040903/eng/jolly_place/maps/fp_tko_popup_2f.htm

Figure A5: Layout map of Pui Shing Garden



Source: drawn by authors

Figure A6: Layout map of Hang Hau Man Kuk Lane Park

Source: drawn by authors