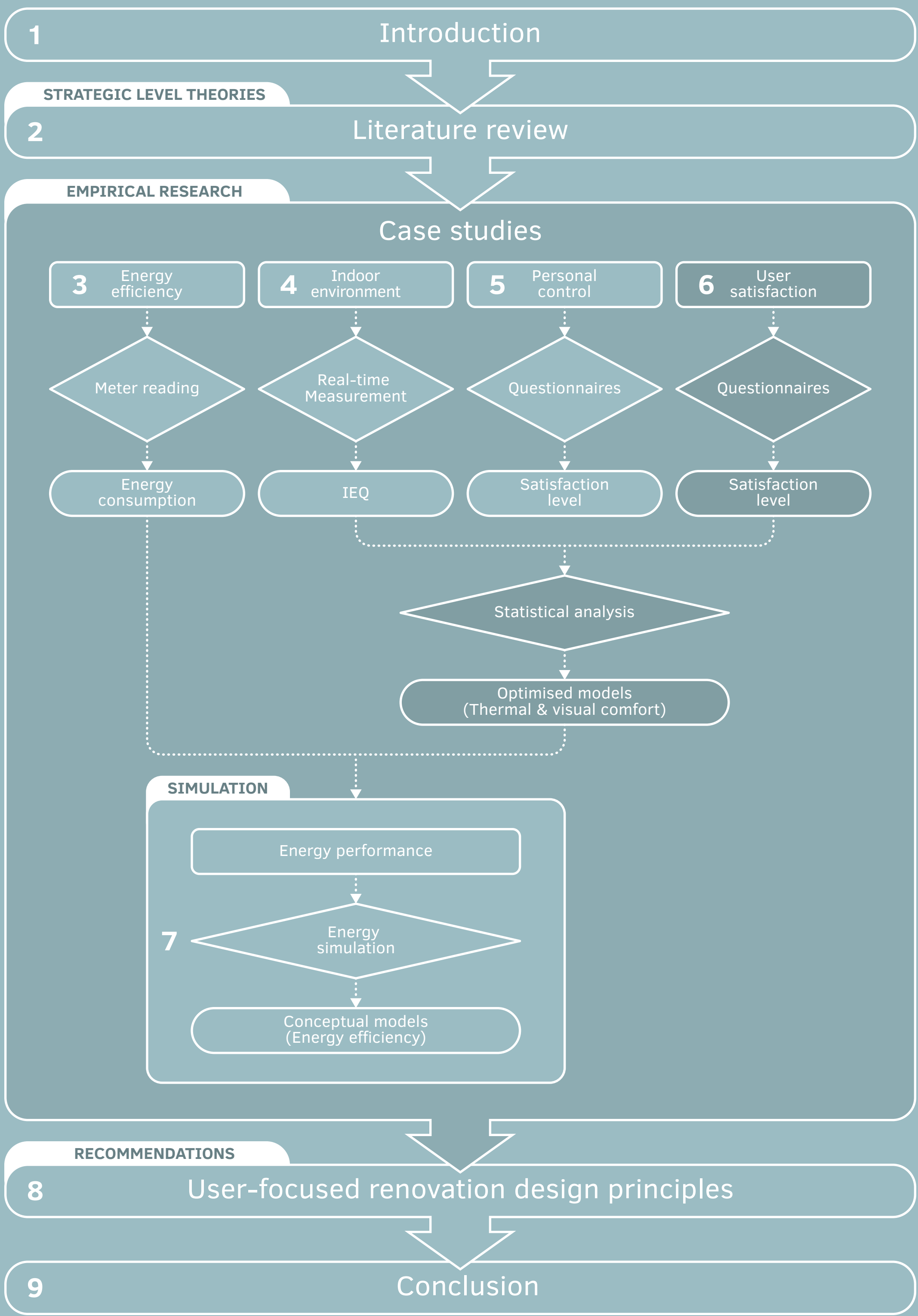

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6 Impact of design factors on user satisfaction

Personal control was one of the influential parameters for user satisfaction presented in chapter 5. Personal control is not related to architectural office design, and in this thesis it is not associated with privacy and communication with colleagues. Thermal and visual comfort is analysed exhaustively in this chapter. Psychological comfort is an extra parameter for user satisfaction studies since the design factors such as office layout could be correlated to privacy, communication and so on. As a next step, chapter 6 investigates influential office design factors on user satisfaction related to thermal, visual, and psychological comfort and predicting which design factors may bring better satisfaction to users.

Section 6.2 presents design factors affecting user satisfaction based on literature review. Five office cases in the Netherlands with 579 office occupants were studied using questionnaires, and interviews with facility managers and architects (section 6.3). Different statistical analysis tests were conducted to summarise satisfaction factors (section 6.4). The relative importance of design factors is described in section 6.5, and a regression analysis was used to predict profound outcomes in section 6.6.

6.1 Introduction

User satisfaction in offices has been studied across disciplines such as social science, real estate, and building environment from different perspectives. The term 'user satisfaction' in the built environment has not been clearly defined. According to Cambridge dictionary, *satisfaction* is a pleasant emotion, when the expectations, or needs, are fulfilled or there is nothing to complain about. Frontczak et al. (2012) reviewed 10 studies related to occupants' satisfaction and stated occupants' satisfaction is highly related to indoor environmental quality or to the workspace. Particularly, indoor environmental quality (IEQ) is one of the key issues for users' satisfaction. This is because occupants' satisfaction with environmental quality affect users' health and comfort perception (Sant'Anna et al., 2018). For these reasons, users' perception and satisfaction of the space they use should be underscored in the built environment (Sant'Anna et al., 2018). In addition, Samani (2015) revealed that users' dissatisfaction normally comes from more than one ambient condition of the workplace. It also may come from composite physical workplace conditions such as location of their working desk, orientation of façade, cellular or open-plan layout, etc.

Despite of the importance of users' satisfaction in building performance, there are many problems in the built environment due to exclusion of the users' perspective. During the conceptual design phase of a building, many decisions are made based on the energy performance, indoor quality, and economic conditions, while the design phase has not adopted end-users' requirement and satisfaction because there is no standard principle and a lack of actual information about their requirements/needs (Heydarian et al., 2017). Huber et al. (2014) classified the number of publications dealing with criteria influencing user satisfaction according to types of buildings. For office buildings, air quality, temperature and lighting were the most frequently studied parameters followed by HVAC usability, and outside views through windows (Attia, 2018; Choi & Moon, 2017; Oseland, 2009; Van der Voordt, 2004). However, the empirical studies examined the impact of IEQ on user satisfaction, but not how building design factors affect user satisfaction with indoor environment. When the users are considered in the early design phase, the design approach may be different than in conventional design approaches in which users are not considered. Rupp et al. (2015) stated that contextual factors such as architectural features, space layout, behavioural aspect, demographic characteristics can also affect occupant's thermal perception.

Another issue in user satisfaction studies is the psychological aspect. Environmental psychology has been studied by empirical research from the ergonomics field, which normally gives immediate responses towards the working environment. In Europe, the environmental psychology of office users has analysed the individual and organisational level (Sundstrom & Sundstrom, 1986). A recent trend in the research field favours physical comfort of office users, which is also called satisfaction with working conditions assessed by post occupancy evaluation. However, early studies by Altman (1975) developed the connection of physical environment and users through social-psychological analyses, including privacy and territoriality. Many studies have highlighted the importance of user satisfaction for promoting work performance and productivity (De Been & Beijer, 2014; Tanabe et al., 2015). Van der Voordt (2004) and Tanabe et al. (2015) stated that higher employee satisfaction in workplaces leads to increased productivity, whereas lack of privacy and territorialism can cause decrease of the satisfaction and productivity. Thus, it is essential to understand employees' perception, and how workplaces are used for better support the office users.

The field of environmental psychology explores the association between human and physical conditions (Oseland, 2009). According to Oseland (2009), people seek enclosed place for concentration on work. At the same time, they also seek social spaces for casual interaction with colleagues. The measurements of environmental satisfaction has been studied by some projects, for instance, The OFFICAIR project (Sakellaris et al., 2016), and the COPE project (Veitch et al., 2007). In spite of numerous studies regarding environmental satisfaction, (Frontczak & Wargocki, 2011) stated that the relationship between indoor environment and end-users' comfort is not fully identified. In addition, the relationship between various design factors (e.g., orientation, WWR, and distance of desk location from window) and psychological satisfaction in offices is rarely known, and very few studies investigated this relationship.

A review by Rolfö et al. (2018) found that psychological workspace comfort such as privacy and territoriality (De Croon et al., 2005), and communication (Brennan et al., 2002) affect occupants' satisfaction and performance as well as physical office conditions (Brill & Weidemann, 2001). Some studies explored the impact of physical environmental factors on job satisfaction and productivity. For instance, Banbury and Berry (2005) compared the effect of noise on users' concentration between cellular and open-plan offices. Similarly, Kaarlela-Tuomaala et al. (2009) studied the different acoustic environment and the degree of users' concentration between those two office layouts. De Been and Beijer (2014) revealed that office type is a significant predictor for employees' productivity, concentration, communication etc. The studies regarding office layout often compare only cellular and open plan types. However, De

Been and Beijer (2014) included combi and flex office types in their study. Kwon et al. (2019) found that prominent psychological variables are privacy, concentration, communication, social contact, and spatial comfort (territoriality).

Therefore, the primary purpose of this chapter is to examine the effect of building design factors on user satisfaction with thermal, visual, and psychological comfort through the field study and provide insight by reporting on the satisfaction differences according to different design factors in offices. This chapter aims to answer the research question: What is the relationship between the office design factors and user satisfaction with thermal, visual, and psychological comfort? And can the relationship be predictable to develop user-focused design principles? Answering these questions, this chapter examines the relationship between different design factors and user satisfaction, and investigates the significant design factors that highly contribute to increasing employees' satisfaction. Finally, predicted satisfaction models are suggested to improve environmental satisfaction in workspaces, and it also offers an overview of influential factors for the workspace design based on the thermal, visual, and psychological satisfaction.

6.2 Design factors for office design: literature review

6.2.1 Keywords selection

Prior to proceeding with the methodology, the main design factors affecting occupant satisfaction and energy performance of the office building are described in this section. The key search terms of the literature search were applied as follow: (office design elements or office design factors or office design) AND (energy efficiency) AND (user satisfaction or occupant satisfaction) AND NOT (school) AND NOT (house) AND NOT (hospital). 17 papers were selected based on the purpose of this research, which is to predict the correlation of physical design factors for office buildings with the level of IEQ and psychological satisfactions.

6.2.2 Design factors influence on user satisfaction

TABLE 6.1 A summary of influential design factors for user satisfaction based on literature reviews

Authors	Design factors	Findings
Danielsson and Bodin (2008)	Office design	Individual's perception related to health and job satisfaction are different according to office types.
Seddigh et al. (2015)		Office layout influences occupants' health and performance.
Zerella et al. (2017)		Layout features are highly associated with employee perception of work satisfaction.
Lee (2010)		Office layout affects worker perception regarding environmental quality issues (LEED-certified buildings)
Schiavon and Altomonte (2014)		Open space layout in LEED buildings showed successful improvement of occupant satisfaction with IEQ, including office type, spatial layout, distance from window, occupants' demographics, occupancy hours.
Baird et al. (2012)		Office layout is a major factor affecting overall occupant comfort.
Shahzad et al. (2017)		Cellular office equipped with personal thermal control showed 35% higher satisfaction and 20% higher comfort level compared to open plan offices.
Rao (2012)		Open space layout will cause reduction of acoustic quality.
Mofidi and Akbari (2018)	Desk location, and dimension	Position-based comfort depends on the dimension of the office, orientation, desk location and placement of openings.
Kong et al. (2018)	Environmental variations	Distance from windows, orientations and window heights significantly affect user satisfaction with daylight and visual comfort.
Dodo et al. (2013)	Façade design and orientation	Orientation, and area of windows determine daylight quality and thermal condition.
Hua et al. (2014)	Façade design	Glazing and shading designs need to be considered for thermal and daylight performance
Tzempelikos et al. (2007)		The impact of WWR and glazing type on thermal comfort was studied for optimal choice of a façade.
Lee et al. (2013)		The study tested building performance based on the relationship between WWR and orientation.
Jin and Overend (2014)		The impact of façade-intrinsic and extrinsic design factors (e.g., WWR, thermal properties, and orientation HVAC system) are evaluated in chamber-based research.
Hua et al. (2014)	Orientation	Orientation is an important factor for thermal and visual comfort and energy efficiency of workspaces.
Konis (2013)		Visual discomfort observed frequently in S.E perimeter zone due to direct sun-light.
Rao (2012)		Building orientation determines solar radiation.

TABLE 6.1 shows a summary of design factors that have been investigated in other studies. Although there are many studies related to occupants' satisfaction with energy efficiency in office buildings, and the impact of façade components and office layout on IEQ, only a few studies deal with the relationship between user satisfaction or comfort and design factors. The office design factors can be divided into two categories with sub-parameters: spatial office design such as layout and position of work places, and façade design such as orientation, window-to-wall ratio (WWR). The effective façade design gives influence on IEQ and user satisfaction as well as orientations. Hua et al. (2014) revealed that the level of occupant's satisfaction with IEQ was different according to orientations. However, office types such as individual office and shared office was not statistically significant.

Based on previous studies, design factors can be classified as four factors: office layout, desk location, orientation, and WWR.

Office layout

In early studies, office layouts were classified by different dimensions. Vos et al. (2000), an idea of an office layout was classified by location, the internal configuration of space and the use of space. Dobbelsteen (2004) defined workplace layout in terms of spatial concepts which have an influence on the interaction of people, the type of climate control, spatial flexibility and spatial efficiency. Danielsson and Bodin (2008) defined office types by different architectural and functional features.

The cellular layout provides individual workspace along the façade accommodating 1-3 workplaces in one cell (Vos et al., 2000). The single cell provides a work environment for high concentration and people can adjust their own preferred indoor climate. The open-plan office type emphasises flexibility of space, sharing workspace with more than 13 persons (Vos et al., 2000). For this type, people complained about the quality of the indoor climate, for instance regarding unpleasantly high or low temperatures, lighting and noise levels etc. The combi-office is an office type that integrates the single-cell type and open-plan type, combined with more types of spaces (Danielsson & Bodin, 2008; Dobbelsteen, 2004). This type is a group work-based plan, and adapted advantages of cellular and open-plan offices (Dobbelsteen, 2004). Employees can work independently, and at the same time, the office provides open space where people can relax and communicate. Flex-office means that no individual workstation includes backup spaces. It is dimensioned for <70% of the workforce to be present simultaneously (Danielsson & Bodin, 2008).

Desk location

Desk location here indicates work desk's distances from windows, having a direct effect on satisfaction with IEQ (Frontczak et al., 2012; Kim et al., 2013). With the importance of this factor, Mofidi and Akbari (2019) developed a position-based evaluation method for user comfort and energy management. Recent studies of Kong et al. (2018) tested occupant's satisfaction with their visual comfort based on the distance from windows. They noted that a location 2.3 m from the windows can protect the building users from the direct sunlight. Awada and Srour (2018) and Altomonte et al. (2019) classified the parameter based on the location of desks within 4.6 m and further than 4.6 m from the nearest window. A study of Christoffersen and Johnsen (2000) measured the satisfaction rate according to the position of desks in window, mid, and wall zones, with less than 7 m depth. They monitored light quality at 2 m from the window. By considering these early studies, desk location comprised three groups in this research: 0-2 m, 2-4m and over 4 m.

Orientation

Seating orientations contribute to the visual comfort in offices (Galasiu & Veitch, 2006; Konis, 2013). In the same way, Hua et al. (2014) stressed that orientation is highly correlated to the visual comfort, especially extreme illuminance was observed in both southwest and northeast orientation. The studies also reported that certain orientations caused high levels of thermal dissatisfaction. However, it is difficult to say that orientation was the main reason that causes occupant's discomfort since other factors such as glazing area, artificial lighting, and blinds may also affect occupants' visual comfort.

Window-to-wall ratio (WWR)

Many studies stated the importance of the glazing area for thermal comfort and daylight (Dodo et al., 2013; Hua et al., 2014; Lee et al., 2013; Tzempelikos et al., 2007). WWR has an impact on building performance in terms of indoor quality due to the influence on natural daylight, heat gain/loss and optical properties, and windows and outside views are psychologically important to employees (Smith & Pitt, 2011; Yildirim et al., 2007). The WWR is calculated by dividing the glazed/window areas by the gross exterior wall area for a particular facade. In other words, it is the ratio between the transparent area versus and the opaque area of the facade. Goia et al. (2013) claimed that the range of 35-45% of WWR is the optimal rate in terms of energy minimisation. This result can be applied to Atlantic and Central Europe only.

Further research of Goia (2016) proposed WWR ranges and orientations for different climate conditions in Europe. Köppen Classification for The Netherlands is Cfb (Marine West Coast Climate). According to Goia (2016), WWR for Cfb classification is 37-45% for south, 40-45% for north, 37-43% for west, and 37-43% for east orientation. Modern offices often have a fully glazed façade. In order to cover the various range of WWR of office buildings, the WWR was classified by three types: 30%, 50%, and 80%.

6.3 Methodology

This chapter examines the impact of design factors on user satisfaction. User surveys and statistical analyses were used to answer the sub-research question. The samples of occupants are the same as those who participated in the previous user survey. Therefore, the number of participants is the same as the previous dataset. To collect accurate information about the physical conditions of their workplace, each user should answer the questions about the workspace conditions they use. Additionally, a map showing the placement of their office building was provided to collect the correct answer about where their workspace is oriented.

6.3.1 Questionnaires

Post-occupancy evaluation (POE) was used to assess building related occupants' feedbacks since the POE tool is useful to investigate how the building performance or environment affect occupants (Vischer, 2002). The questionnaires included design factors such as desk location, orientation, window-to-wall ratio (WWR), and office layout (see TABLE 6.2). Psychological user satisfaction was measured by the following questions: 'How satisfied are you with the following conditions?' regarding privacy during work at your workstation, opportunity to concentrate on your work, opportunities to communicate for work, social contact with colleagues in the office, and feeling of territoriality. In order to investigate the degree of user satisfaction with psychological comfort in the work environment, the following question was asked: 'How satisfied are you with the following conditions?', applying five psychological satisfaction variables, and 'what are the most important issues for better work environment?'. These variables measure the degree of satisfaction using a fivepoints Likert scale ranging from 1=extremely dissatisfied, 2=dissatisfied, 3=neither dissatisfied nor satisfied, 4=satisfied, 5=extremely satisfied.

TABLE 6.2 Questions about physical condition of workplaces

Categories	Question	Answer
Design factors		
Desk location	Where is your desk located?	1 = 0-2m away from windows 2 = 2-4m away from windows 3 = Over 4m away from window
Orientation	Which direction does your window face?	1 = South-east 2 = South-west 3 = North-east 4 = North-west
WWR	What types of windows does your workplace have? (Choose what comes closest to your situation)	1 = 30% 2 = 50% 3 = 80%
Office layout	What type of office layout do you work at?	1 = Cellular 2 = Open plan 3 = Combi-office 4 = Flexible office
Psychological satisfaction parameters		
Better work environment	What is the most important issue for better work environment?	1 = Privacy 2 = Concentration 3 = Communication 4 = Social contact 5 = Territoriality
Satisfaction	How satisfied are you with the following conditions? (Privacy, concentration, communication, social contact, and territoriality)	1 = Extremely dissatisfied, 2 = Dissatisfied, 3 = Neither dissatisfied nor satisfied, 4 = Satisfied 5 = Extremely satisfied

6.3.2 Statistical data analysis

The survey recorded the degree of satisfaction on an ordinal scale. A mean satisfaction score and percentile were used to understand how satisfied users were with psychological variables in their work environment. First, Cronbach's Alpha was tested to determine if the Likert scale was reliable. Second, the normality was checked by one-sample Kolmogorov-Smirnov test, before conducting the Kruskal – Wallis H test (KWH) which determines that the satisfaction variances are correlated with nominal dependent variables. This test assesses the difference among independent sample groups in non-normally distributed data (Vargha & Delaney, 1998). As following up test of the KWH test, a non-parametric post hoc test was conducted by pairwise comparison to examine which groups show differences.

The number of dependent variables (satisfaction parameters) had to be reduced to fewer dimensions by grouping similar patterns of responses. The process can simplify the data and prevent multi-collinearity error. Factor analysis was conducted to establish the underlying data structure with Oblimin rotation (oblique solution), to find out if the factors were correlated (Jackson, 2005). Two factors (e.g., thermal-related satisfaction and visual-related satisfaction) were identified to explain over 70% of the variance in the data structure by the factors that were extracted. Aggregate variables were created based on the factor analysis and henceforth these were recoded into binominal variables to create a redundant and more powerful model. However, the collected dataset showed non-normal distributions.

Categorical regression (CATREG) (McCullagh, 1980), also called regression with optimal scaling (Angelis et al., 2001), circumvents this problem by converting nominal and ordinal variables into interval scales (Meulman, 1998), and also circumvents the issue of unequal sample sizes between the cases since the analysis uses a weighted average according to (IBMKnowledgeCenter). This analysis identify a direct probability model and the predictors (independent variables) of satisfaction (dependent variables) and relative contributions with the variance explained by R^2 (Ibem et al., 2015).

Subsequently, binary logistic regression analysis was used to predict the models for occupants' satisfaction with the given thermal, visual and psychological variables. This analysis has been applied in previous studies (Au-Yong et al., 2014; De Kluizenaar et al., 2016). The independent variables (predictors) were design factors, and the dependent variables were the satisfaction with psychological parameters. In order to conduct the binary logistic regression, the degrees of satisfaction were recoded with the value of 'not satisfied' = 0, 'satisfied' = 1. Goodness of fit of the models was evaluated by the Hosmer-Lemeshow test, which was over the 5% level, revealing that the satisfaction could be explained by the models. Desk location, orientation, layout and WWR were entered as explanatory (categorical) variables. The last dummy was the reference category as each category compared against each other.

In order to check whether or not the model is fit to the data, the Hosmer-Lemeshow (Chi-square) (Hosmer et al., 1997) test was conducted. The H0 hypothesis is that the model is a good enough fit with the data ($p<0.05$) that allows to estimate values of the outcome variables (Field, 2015). H1 is that the model is not a good enough fit to the data. The associations are shown as Odds Ratios (OR) with 95% of confidence interval (CI 95%). In general, an OR indicates the likelihood of increasing the value of dependent variables. However, the independent variables are nominal scale and the dependent ones are ordinal scale, thus, ORs are used to compare the relative relationship between the design factors and the satisfaction.

6.4 Overview of measured satisfaction degrees

The Cronbach's Alpha of satisfaction parameters was 0.817, which means a high level of reliability. FIG. 6.1 and 6.2 show a summary of the percentile scores in each physical and psychological satisfaction category. The figure also compared the percentile scores between renovated and non-renovated offices. Overall, the mean values of each satisfaction variable were less than 4 in both physical and psychological categories. The range of satisfaction with thermal and visual comfort was wider in renovated offices than that of non-renovated offices. People in non-renovated offices showed neither satisfied nor dissatisfied on average. On the other hand, there were some people responded that they were dissatisfied with thermal and visual comfort throughout a year.

In terms of psychological categories, the highest mean value was recorded for the 'social contact with colleagues' (mean: 3.80), and the lowest one was 'opportunity to concentrate on work task' (mean: 2.78). Although the occupants in the non-renovated office were slightly more satisfied than those in renovated offices, there was no big difference between the two conditions. Interestingly, people who work in non-renovated offices answered higher satisfaction for privacy and concentration than those in renovated offices. People in renovated offices were more satisfied with social contact with colleagues than those in non-renovated offices. The reason for this is assumed that modern offices often have an open-plan layout, and 1960-70's offices are with a cellular office plan.

	Season	Parameters	Number of participants	Mean (SD)
Renovated cases	Mid-season	Thermal comfort	500	3.10 (0.99)
		Visual comfort	500	2.84 (0.73)
	Summer	Thermal comfort	500	3.10 (1.00)
		Visual comfort	500	2.80 (0.73)
	Winter	Thermal comfort	500	3.06 (0.99)
		Visual comfort	500	2.82 (0.73)
non-renovated cases	Mid-season	Thermal comfort	79	3.50 (0.86)
		Visual comfort	79	3.01 (0.63)
	Summer	Thermal comfort	79	2.98 (0.91)
		Visual comfort	79	2.94 (0.59)
	Winter	Thermal comfort	79	3.44 (0.82)
		Visual comfort	79	2.92 (0.67)

Quartile range

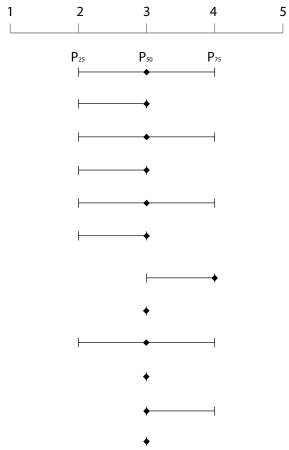


FIG. 6.1 Quartile ranges by physical categories from 1 (extremely dissatisfied) to 5 (extremely satisfied)

	Categories	Number of participants	Mean (SD)
Overall	Privacy	579	2.92 (1.10)
	Concentration	579	2.78 (1.16)
	Communication	579	3.42 (1.02)
	Social contact	579	3.80 (0.91)
	Territoriality	579	3.09 (0.98)
Renovated offices	Privacy	500	2.86 (1.06)
	Concentration	500	2.72 (1.12)
	Communication	500	3.42 (1.00)
	Social contact	500	3.81 (0.89)
	Territoriality	500	3.05 (0.97)
Non-renovated offices	Privacy	79	3.25 (1.26)
	Concentration	79	3.15 (1.32)
	Communication	79	3.41 (1.14)
	Social contact	79	3.77 (1.06)
	Territoriality	79	3.33 (1.03)

Quartile range

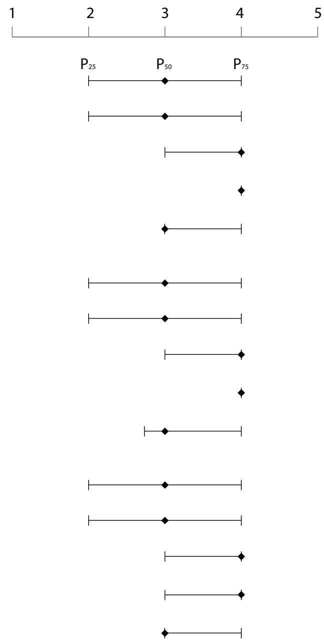


FIG. 6.2 Quartile ranges by psychological categories from 1 (extremely dissatisfied) to 5 (extremely satisfied)

FIG. 6.3 shows the percentage of responses on each satisfaction variable. In detail, 36% of the occupants were dissatisfied with 'privacy' and 43% with 'concentration'. On the other hand, around 60% of the occupants were satisfied with the opportunity of 'communication', and three quarter of the occupants were satisfied with 'social contact'. In terms of 'territoriality', most people tended to be neither satisfied nor dissatisfied, and they were rarely dissatisfied. Remarkably, around 18% of the occupants were extremely satisfied with 'social contact', and only less than 10% of occupants were extremely satisfied with the rest of the variables, whereas occupants were extremely dissatisfied with privacy and concentration with 11% and 16%, respectively.

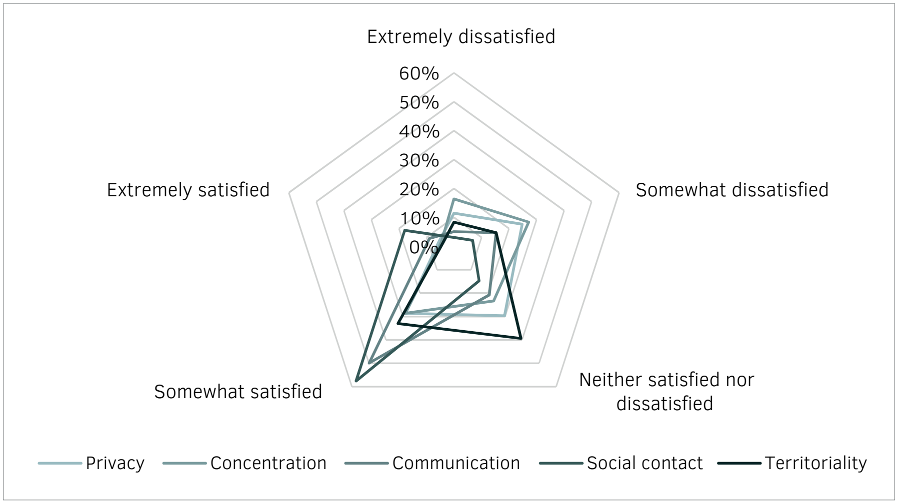


FIG. 6.3 Percentages of measured satisfaction degrees

6.5 Data extraction of user satisfaction variables

The first step in the analysis was to check how the indoor satisfaction variables clustered together and to learn about the underlying structure. Indoor satisfaction variables were analysed with Oblimin rotation of factor analysis. When p-value < 0.05, the test results were considered as statistically significant. Two factors were established: thermal and visual comfort (see TABLE 6.3). The first factor consists of items describing thermal affective dimensions such as temperature, air quality, humidity and overall comfort. Factor 1 was labelled thermal comfort-related satisfaction. The first factor explained 57.0% of variance. The second factor was labelled visual comfort-related satisfaction that consists of view to outside, daylight, and artificial lighting. Together these factors explained over 71.4% of variance. A KMO (Kaiser-Meyer-Olkin measure) and Bartlett's test were conducted to check if these factors met sample adequacy. 0.865 of KMO value exceeded the accepted value of 0.5, and Bartlett's test of Sphericity was significant ($X^2(21) = 2128.70$, $p< 0.001$. This indicates that the samples' adequacy can be accepted and validated the significance of this study. Noise was eliminated from satisfaction factors due to low factor loading (under 0.5), and it represented a different construct. Substantively, two tendencies were identified which are independent of one another.

TABLE 6.3 Results of factor analysis based on structure matrix with Oblimin rotation

	Loadings			
	Factor 1: Thermal comfort-related satisfaction	Factor 2: Visual comfort-related satisfaction	Communalities	Cumulative (%)
Temperature	0.880		0.634	56.979
Air quality	0.874		0.599	
Humidity	0.855		0.722	
Overall comfort	0.793		0.775	
View to outside		0.850	0.738	71.397
Daylight		0.835	0.731	
Artificial lighting		0.700	0.797	
Noise		Eliminated		

6.6 Exploring design factors related to user satisfaction

The categorical regression analysis was performed using the enter method, to identify the relative contribution of influential design factors on user satisfaction and to predict the factors in all seasons. The enter method prevents the elimination of the variables that are significant but have a weak contribution. These regression models, based on two factor models, were designed for each season. The results describe which design factors had substantial contribution to user satisfaction with thermal and visual comfort, and how user satisfaction depends on desk location, orientation, layout and WWR.

TABLE 6.4 shows the relative contribution of influential design factors on thermal and visual satisfaction. R^2 indicates how well the model fits the data.

$$R^2 = \frac{\text{Variance explained by the model}}{\text{Total variance}}$$

The range of R^2 was between 9.0% and 15.0%, which were relatively low R-squared values. However, the regression models showed that independent variables were statistically significant. Therefore, objective variables (desk location, orientation, layout, and WWR) were found to be significant predictors for user satisfaction in the work environments. All objective variables had a positive relationship with satisfaction parameters. β value refers to the standardised coefficient. In detail, the largest coefficient of thermal satisfaction occurred in 'desk location', $\beta = 0.269$, $p < 0.001$, for mid-season, $\beta = 0.230$, $p < 0.001$ for summer, and $\beta = 0.212$, $p < 0.001$ for winter. The largest coefficient of visual satisfaction occurred in 'desk location', $\beta = 0.180$, $p < 0.001$ for mid-season, $\beta = 0.189$, $p < 0.001$ for summer, and $\beta = 0.206$, $p < 0.001$ for winter, followed by 'layout'.

TABLE 6.4 Results of categorical regression analysis (N=579)

	Dependent	Independent	β	Importance	*P*-value	R^2	*P*-value
Mid-season	Thermal satisfaction	Desk location	**0.269**	**0.586**	**p < 0.001**	0.128	*p* < 0.001
		Orientation	0.106	0.131	**p < 0.001**		
		Layout	0.185	0.263	**p < 0.001**		
		WWR	0.046	0.020	0.184		
	Visual satisfaction	Desk location	**0.180**	**0.408**	**p < 0.001**	0.088	*p* < 0.001
		Orientation	0.125	0.214	**p < 0.001**		
		Layout	0.168	0.309	**p < 0.001**		
		WWR	0.069	0.068	**0.026**		
Summer	Thermal satisfaction	Desk location	**0.230**	**0.406**	**p < 0.001**	0.149	*p* < 0.001
		Orientation	0.191	0.306	**p < 0.001**		
		Layout	0.183	0.218	**p < 0.001**		
		WWR	0.094	0.069	**0.007**		
	Visual satisfaction	Desk location	**0.189**	**0.420**	**p < 0.001**	0.093	*p* < 0.001
		Orientation	0.141	0.238	**p < 0.001**		
		Layout	0.162	0.304	**p < 0.001**		
		WWR	0.058	0.038	0.086		
Winter	Thermal satisfaction	Desk location	0.212	**0.386**	**p < 0.001**	0.124	*p* < 0.001
		Orientation	0.126	0.184	**p < 0.001**		
		Layout	**0.213**	0.332	**p < 0.001**		
		WWR	0.110	0.097	**0.001**		
	Visual satisfaction	Desk location	**0.206**	**0.511**	**p < 0.001**	0.092	*p* < 0.001
		Orientation	0.094	0.126	**0.002**		
		Layout	0.167	0.305	**p < 0.001**		
		WWR	0.058	0.059	0.071		

Note: p-values in bold highlighted are statistically significant (p < 0.05),
β coefficients in bold highlighted mean the largest satisfaction coefficient.

To interpret the contributions of four predictors, it is important to inspect Pratt's measure of relative importance. The largest importance corresponded to 'desk location', 'layout', and 'orientation' accounting for over 90% of the importance. Despite of the relatively small standardised coefficient of 'orientation', the large importance of 0.306 occurred in the satisfaction with thermal comfort in summer. In summary, 'desk location', 'layout', and 'orientation' predictors highly contributed to environmental user satisfaction in workplaces.

TABLE 6.5 shows the relative contribution of design factors to predict psychological satisfaction. The range of R^2 was between 5.6% and 14.2%, which shows how well the model fits the data. Overall, WWR was not a statistically significant design factor for the satisfaction with psychological comfort, except for the satisfaction with 'concentration' and ‘territoriality’. ‘Desk location’, ‘orientation’ and ‘layout’ were the significant predictors for psychological user satisfaction in the work environment. The largest coefficient of ‘privacy’, ‘concentration’, and ‘territoriality’ occurred in ‘layout’, β = 0.326, p <0.001, β = 0.248, p <0.001, and β = 0.243, p <0.001, respectively. ‘Orientation’ was the greatest contribution factor for the satisfaction with communication of β = 0.172, p <0.001, and social contact of β = 0.154, p <0.001. Therefore, the factor contributing most to the user satisfaction was ‘layout’ followed by ‘orientation’.

TABLE 6.5 Relative contribution of design factors (results from categorical regression analysis)

Dependent	Independent	β	Importance	*P*-value	R^2	*P*-value
Privacy	Desk location	0.112	0.068	**0.004**	0.142	*p* < 0.001
	Orientation	0.145	0.188	**p < 0.001**		
	Layout	**0.326**	**0.744**	**p < 0.001**		
	WWR	0.018	-0.001	0.779		
Concentration	Desk location	0.092	0.077	**0.009**	0.115	*p* < 0.001
	Orientation	0.207	0.423	**p < 0.001**		
	Layout	**0.248**	**0.489**	**p < 0.001**		
	WWR	0.081	0.012	**0.045**		
Communication	Desk location	0.101	0.160	**0.006**	0.068	*p* < 0.001
	Orientation	**0.172**	**0.507**	**p < 0.001**		
	Layout	0.153	0.335	**p < 0.001**		
	WWR	0.032	-0.002	0.600		
Social contact	Desk location	0.138	0.383	**0.001**	0.056	0.001
	Orientation	**0.154**	**0.457**	**p < 0.001**		
	Layout	0.061	0.036	0.104		
	WWR	0.090	0.124	**0.012**		
Territoriality	Desk location	0.044	-0.004	0.537	0.077	*p* < 0.001
	Orientation	0.112	0.202	**0.001**		
	Layout	**0.243**	**0.774**	**p < 0.001**		
	WWR	0.037	0.027	0.404		

Note: p-values in bold highlighted are statistically significant (p < 0.05),
β coefficients and importance in bold highlighted mean the largest satisfaction coefficient.

FIG. 6.4 illustrates which of the independent design variables have a greater impact on user satisfaction with thermal and visual comfort in different seasons. Taken together, ‘desk location’ and ‘layout’ showed greater impact on thermal and visual comfort regardless of seasons. On the other hand, ‘WWR’ was the least important predictor for satisfaction with thermal comfort, and the variable did not significantly attribute to visual comfort in summer and winter but mid-season. Although ‘orientation’ was a significant predictor, the beta weight was relatively smaller than that of ‘desk location’ and ‘layout’.

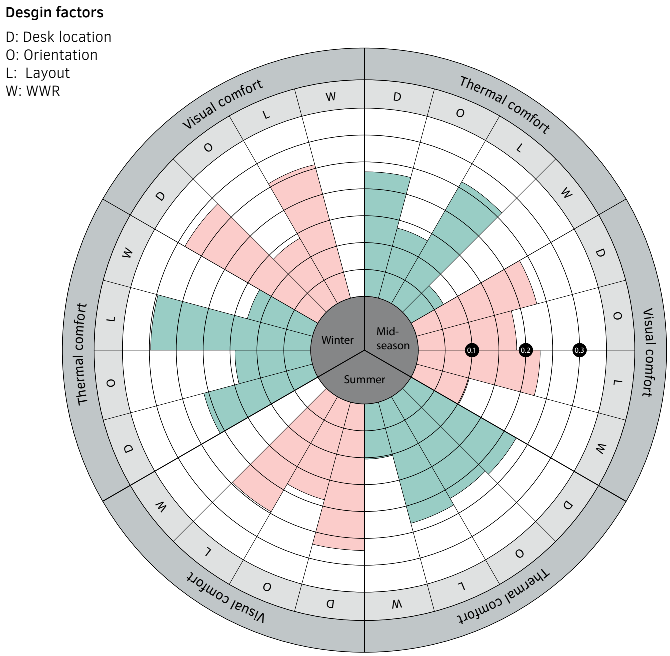


FIG. 6.4 Influential weight of design factors on user satisfaction with thermal and visual comfort

FIG. 6.5 illustrates the influential weight of design factors based on TABLE 6.5. According to FIG. 6.5, 'layout' must be considered as the most important design factor for 'privacy', 'concentration', and 'territoriality', and relatively low contribution for 'communication'. In contrast, the factor was not statistically significant for 'social contact'. 'Orientation' was the second significant design factor of all satisfaction variables. In contrast, WWR was only presented as a statistically significant factor to concentration and social contract.

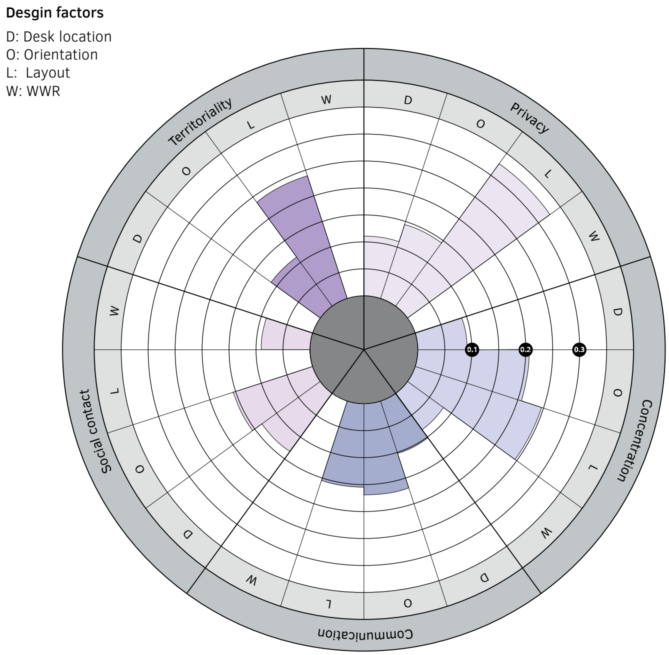


FIG. 6.5 Influential weight of design factors on psychological satisfaction factors

FIG. 6.6 displays nominal transformation plots for design factors. It shows the relationship between the quantifications and the independent categories selected by optimal scaling level. It was created based on categorical regression. It shows the tendency of user satisfaction for design factors. The X axis represents the order of the codes used in each parameter, and the Y axis represents the quantification values of transformed dependent variables.

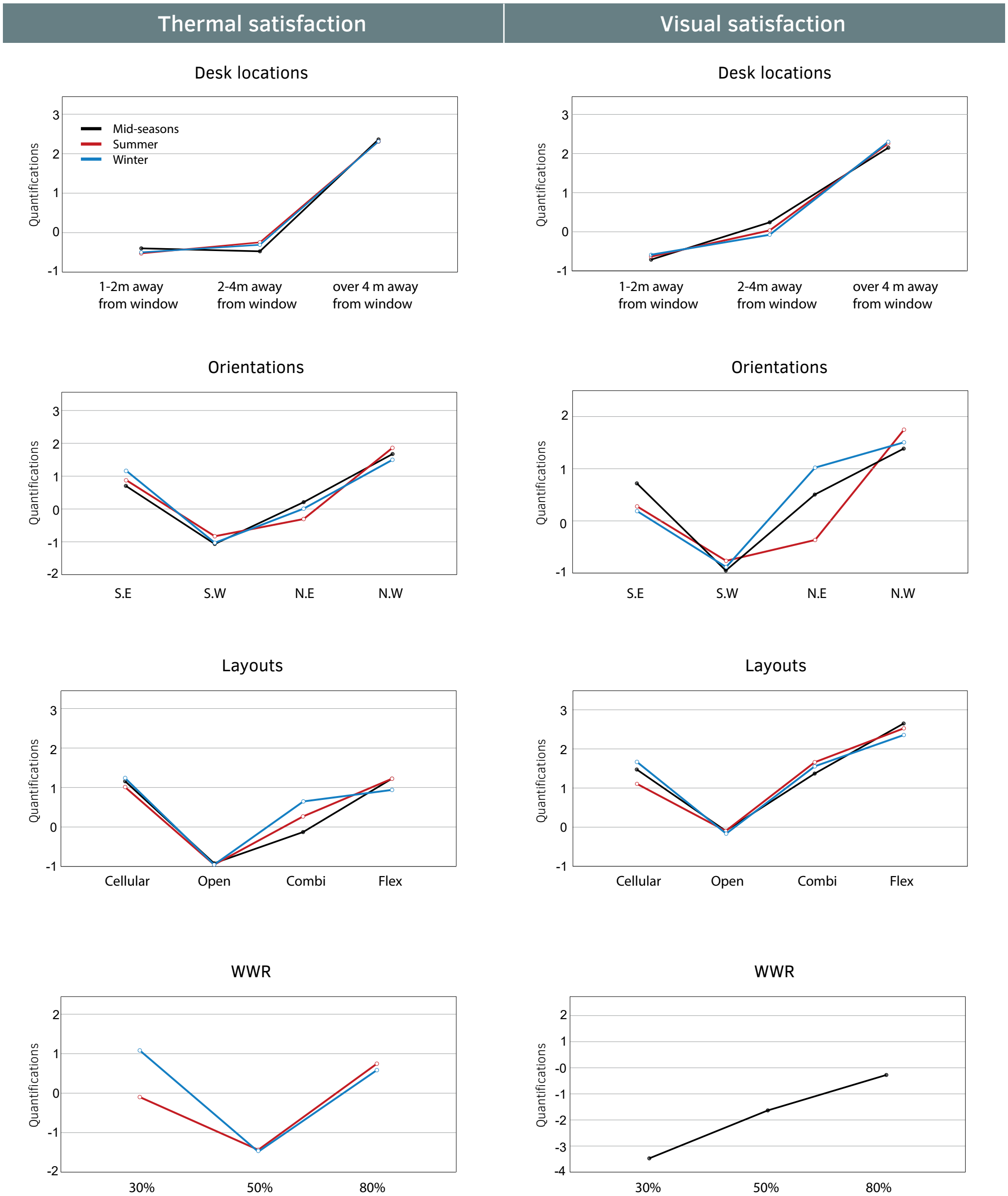
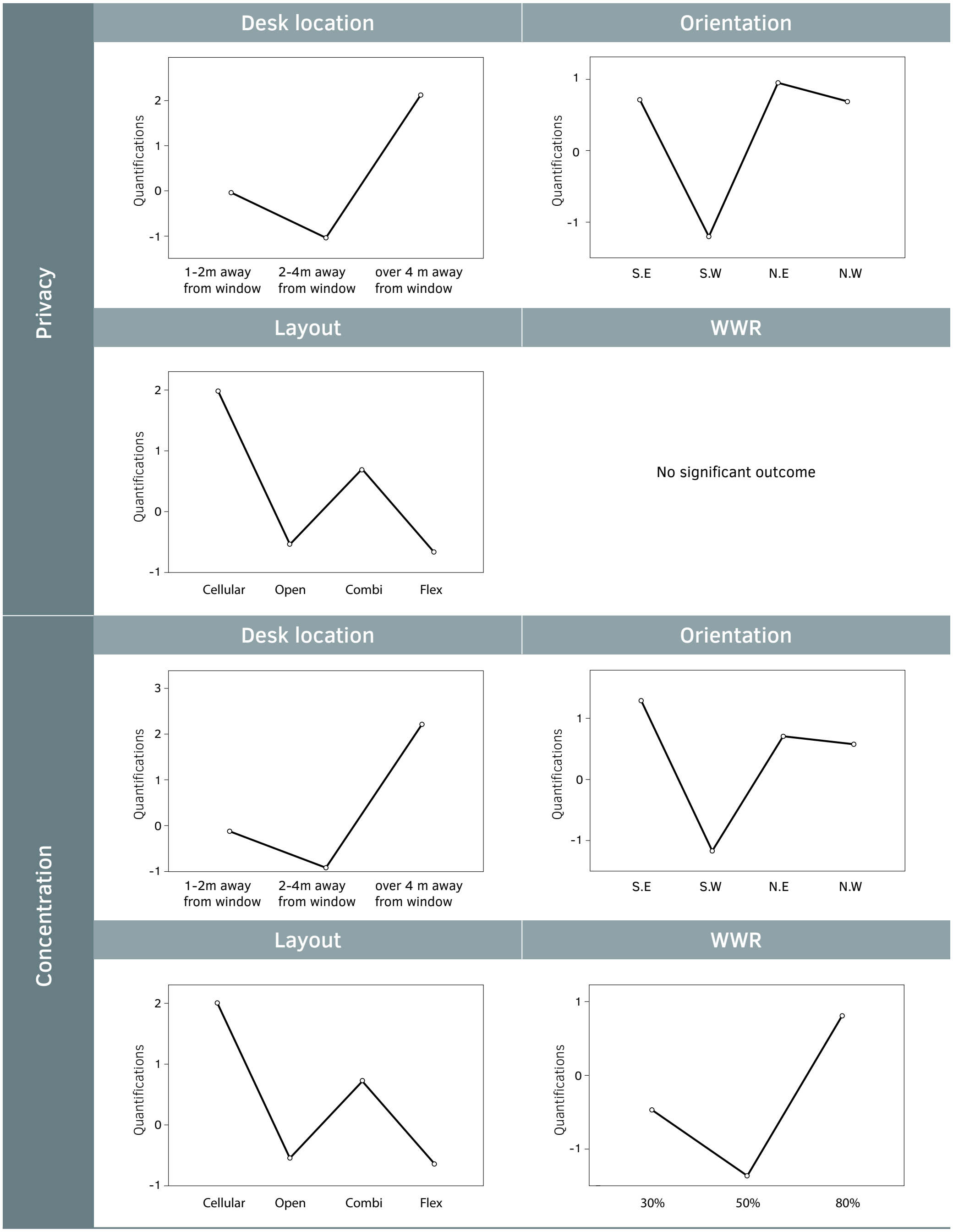


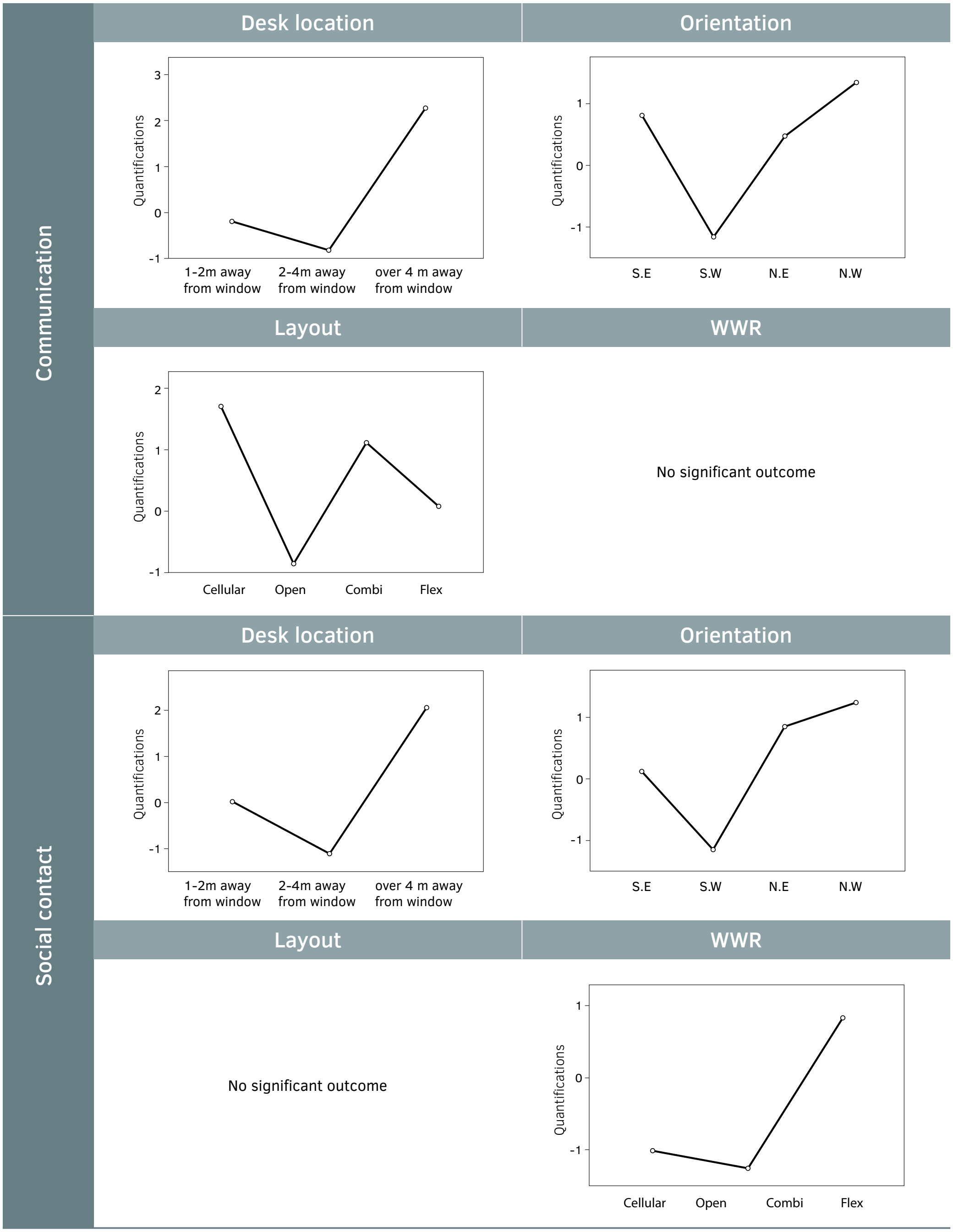
FIG. 6.6 The relationship between design factors and user satisfaction with thermal and visual comfort based on categorical regression

The original values of dependent variables are categorical; therefore, the values were transformed to numerical quantification through the optimal scaling. The procedure of transformation allows categorical variables to be analysed to find the best-fitting model (Shrestha, 2009). The transformed quantifications are the values assigned to each category to make non-linear relation and reflects characteristics of the original categories (Meulman & Heiser, 1999). Therefore, each quantification value itself is not important. For example, 'over 4m distance from windows' showed the largest quantification, therefore, increasing the predicted satisfaction level. First, for the desk location placed far away from windows, people were more satisfied with the thermal and visual satisfaction. Second, cellular office as one of four layouts showed the highest satisfaction for thermal comfort in mid-season and winter among four layouts. In summer, however, the flexible office showed a higher thermal satisfaction than the cellular type. On the other hand, open-plan office was the worst layout for thermal comfort for all seasons. For visual satisfaction, the pattern was quite similar, but combi and flexible offices tended to be preferred and resulted in higher visual satisfaction. Next, the orientation that the occupants were most satisfied with was north-west, and least satisfied was south-west for both thermal and visual satisfaction. The results of thermal satisfaction in mid-season, and visual satisfaction with comfort in summer and winter according to WWR were not statistically significant. Therefore, the graphs were eliminated.

FIG. 6.7 presents the tendency of user satisfaction with psychological comfort according to the nominal design factors. The β values in TABLE 6.5 were positive, and therefore the higher Y axis values indicate the higher predicted satisfaction level. The design factors which were not significant for a certain satisfaction variable were eliminated. In detail, the desk location over 4m away from windows was predicted to increase user satisfaction with psychological comfort variables, except for territoriality. However, the contribution weight of 'desk location' was not as high as other design factors. The most notable outcome in the categorical regression analysis was 'office layout'. The probability of higher satisfaction with privacy, concentration, and territoriality was shown in the order of cellular > combi > open > flex-office, whereas the probability of higher satisfaction with communication was presented as following the order of cellular > combi > flex > open-plan office.


Privacy
Desk location
Orientation
Layout
WWR
No significant outcome
Concentration
Desk location
Orientation
Layout
WWR
Quantifications
1-2m away from window
2-4m away from window
over 4 m away from window
S.E
S.W
N.E
N.W
Cellular
Open
Combi
Flex
30%
50%
80%

TOC


Communication
Desk location
Orientation
Layout
WWR
No significant outcome
Social contact
Desk location
Orientation
Layout
WWR
No significant outcome
Quantifications
1-2m away from window
2-4m away from window
over 4 m away from window
S.E
S.W
N.E
N.W
Cellular
Open
Combi
Flex

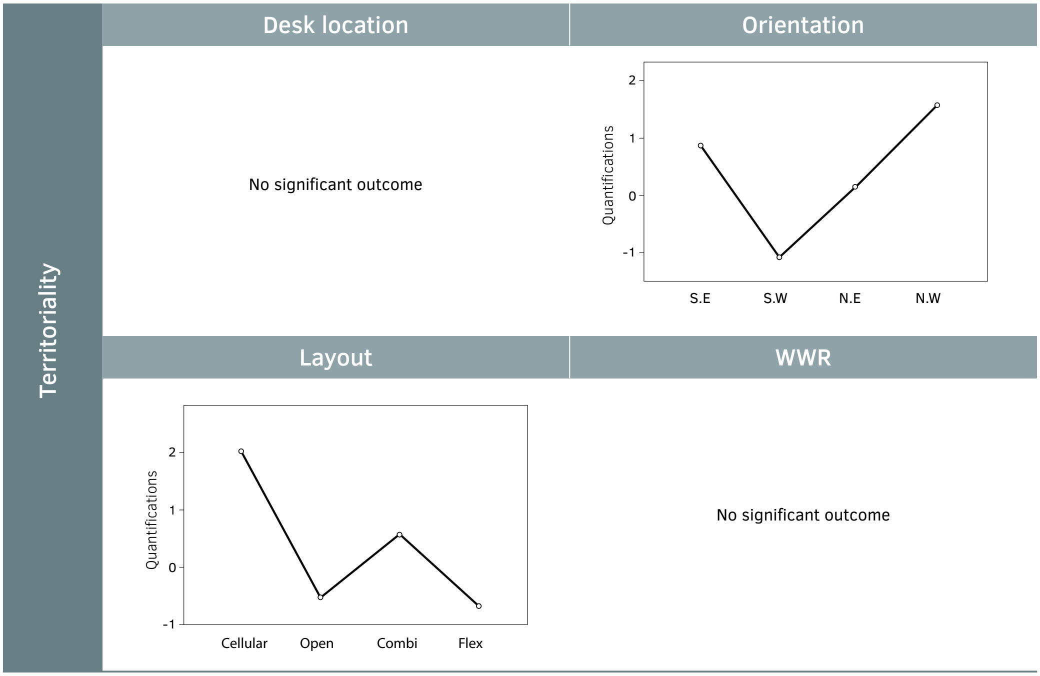


FIG. 6.7 The relationship between design factors and user satisfaction with psychological comfort based on categorical regression

6.7 Predicted environmental and psychological user satisfaction models

Based on a categorical regression test, variables of ‘desk location’, ‘layout’, and ‘orientation’ were further examined by the binary logistic regression using office design factors as the dependent variable and thermal and visual satisfaction as the independent variable. Nagelkerke R^2 (Nagelkerke, 1991) shows that the model explains roughly 20-25% of the variation in the outcome. Hosmer-Lemeshow test indicates goodness of fit for logistic regression. The *p*-value was higher than 0.05 so that the model fits the data.

TABLE 6.6 presents the results of the logistic regression reporting a regression coefficient (B), an odds ratio (β), and *p*-value. In the model, one less than the number of categories were created as dummy variables. Therefore, desk location over 4m away from window, N.W, and flex-office layout were omitted, and calculated as the base variables. The results represent that there was a statistical significance between desk location and environmental satisfaction. In detail, occupants who sit over 4m away from the windows were 3.85-5.71 times more satisfied with the thermal comfort than those who sit closer to the windows, and 2.65-7.25 times more satisfied with the visual comfort. The impact of orientation on satisfaction was only significant for thermal satisfaction in summer, and visual satisfaction in mid-season and summer. South-west and north-west façade had strong impact on thermal and visual comfort, mainly in summer. Occupants of workplaces facing to the north-west orientation were 3.53-4.50 times more satisfied (followed by those who sit on the north-east) than were people facing south-west. As the results of categorical regression analysis shows, office layout was an important predictor for environmental satisfaction for all seasons. The prediction impact between open plan and flex-office was significant, $p < 0.05$. The occupants in flex-office tended to be 3.55-4.07, and 3.90-4.85 times more satisfied with thermal and visual comfort respectively than those in open-plan offices.

TABLE 6.6 Results of binary logistic regression of design factors and IEQ user satisfaction: Hosmer-Lemeshow test, Odd-ratios are reported with confidence intervals parentheses and P-value (N = 579)

Satisfaction with thermal comfort						
Variable	Moderate season		Summer		Winter	
	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value
Desk location		***p* < 0.001**		***p* < 0.001**		**0.001**
0-2m	**0.20 (0.08-0.44)**	***p* < 0.001**	**0.18 (0.08-0.40)**	***p* < 0.001**	**0.23 (0.10-0.50)**	***p* < 0.001**
2-4m	**0.22 (0.09-0.49)**	***p* < 0.001**	**0.20 (0.09-0.47)**	***p* < 0.001**	**0.26 (0.11-0.60)**	**0.002**
Orientation		0.069		***p* < 0.001**		0.070
S.E	0.63 (0.24-1.63)	0.343	0.53 (0.20-1.37)	0.191	0.69 (0.27-1.75)	0.433
S.W	0.38 (0.18-0.80)	0.011	**0.22 (0.10-0.47)**	***p* < 0.001**	0.38 (0.18-0.81)	0.012
N.E	0.50 (0.23-1.08)	0.080	**0.28 (0.12-0.58)**	**0.001**	0.52 (0.24-1.13)	0.099
Layout		**0.000**		***p* < 0.001**		***p* < 0.001**
Open	1.09 (0.47-2.57)	0.836	0.79 (0.36-1.73)	0.552	1.14 (0.48-2.70)	0.760
Combi	**0.28 (0.15-0.53)**	***p* < 0.001**	**0.28 (0.15-0.52)**	***p* < 0.001**	**0.25 (0.13-0.48)**	***p* < 0.001**
Flex	0.44 (0.18-1.09)	0.077	0.55 (0.22-1.38)	0.202	0.63 (0.25-1.61)	0.338
WWR	-	-	-	-	-	-
30%	-	-	-	-	-	-
50%	-	-	-	-	-	-
	R^2	0.210	R^2	0.255	R^2	0.224
	HL test	0.535	HL test	0.700	HL test	0.423
	Classification (%)	66.5	Classification (%)	68.0	Classification (%)	67.3
Satisfaction with visual comfort						
Variable	Moderate season		Summer		Winter	
	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value
Desk location		**0.002**		***p* < 0.001**		***p* < 0.001**
0-2m	**0.19 (0.07-0.49)**	**0.001**	**0.14 (0.05-0.38)**	***p* < 0.001**	0.14 (0.05-0.37)	***p* < 0.001**
2-4m	**0.38 (0.15-0.98)**	**0.045**	**0.30 (0.11-0.79)**	**0.015**	0.20 (0.07-0.53)	**0.001**
Orientation		**0.038**		**0.034**		0.165
S.E	0.45 (0.15-1.30)	0.141	0.57 (0.20-1.66)	0.304	0.55 (0.18-1.66)	0.292
S.W	**0.28 (0.11-0.68)**	**0.005**	**0.28 (0.11-0.71)**	**0.007**	0.34 (0.13-0.91)	0.031
N.E	0.52 (0.21-1.32)	0.170	0.65 (0.25-1.68)	0.370	0.61 (0.23-1.63)	0.322
Layout		**0.005**		**0.002**		**0.002**
Open	0.59 (0.22-1.60)	0.300	**0.34 (0.12-0.96)**	**0.042**	0.38 (0.13-1.08)	0.069
Combi	**0.26 (0.12-0.56)**	**0.001**	**0.21 (0.09-0.46)**	***p* < 0.001**	0.23 (0.10-0.50)	***p* < 0.001**
Flex	0.53 (0.19-1.54)	0.245	0.35 (0.12-1.06)	0.064	0.69 (0.23-2.14)	0.526
WWR	-	-	-	-	-	-
30%	-	-	-	-	-	-
50%	-	-	-	-	-	-
	R^2	0.229	R^2	0.248	R^2	0.245
	HL test	0.743	HL test	0.515	HL test	0.917
	Classification (%)	68.7	Classification (%)	75.0	Classification (%)	71.5

Note: B coefficients and odd ratio (β) in bold highlighted are statistically significant (p < 0.05)

A binary logistic regression was used to predict the impact of design factors on psychological user satisfaction, The data were recoded to dependent variables (satisfied, not satisfied), and each design parameter was analysed as dummy variables. This analysis validated the categorical regression result, and used the enter method to include the predictors that significantly contributed to the regression model.

In TABLE 6.7, the significance of regression models was tested by the Omnibus test ($p < 0.05$). The model explained 4-12% (Nagelkerke R^2) of the variance in satisfaction and correctly classified over 60% of the cases. The data were fit for the logistic regression analysis, showing over 0.05 of p-value tested by the Hosmer-Lemeshow analysis. The significant relationships contributing to satisfaction were found for 'layout', 'desk location', and 'orientation'. On the contrary to the result of CATREG, the variable 'orientation' was not statistically significant for psychological satisfaction, except for 'concentration'. In detail, occupants in cellular offices were 3.4 times (OR 0.29, 95% CI: 0.17-0.49) more likely to be satisfied with privacy, 2.7 times (OR 0.37, 95% CI: 0.21-0.63) more with concentration, and 1.8 times (OR 0.55, 95% CI: 0.33-0.90) more with territoriality than those who work in open-plan offices. The cellular office users also tended to be 3.7 times (OR 0.27, 95% CI: 0.15-0.5) more satisfied with privacy, 3.0 times (OR 0.33, 95% CI: 0.17-0.61) more with concentration, and 2.2 times (OR 0.45, 95% CI: 0.25-0.81) more with territoriality than those who work in flex-offices. 'Desk location' was an important predictor for psychological satisfaction variables except for 'concentration'. Remarkably, occupants sitting over '4m away from windows' were 2-2.5 times more satisfied than those sitting '2-4m away from windows', and 2-2.2 times more than the group of occupants sitting '0-2 m away from window'. Although 'orientation' was the second significant factor for the satisfaction in the results of the categorical analysis, this design factor was only significantly predicting the satisfaction with concentration. People in the workstations oriented to N.W tended to be more satisfied with concentration than those working in S.W. oriented workstations, and no statistical significance was found for WWR.

TABLE 6.7 Results of binary logistic regression of design factors and psychological user satisfaction: Hosmer-Lemeshow test, Odd-ratios are reported with confidence intervals parentheses and P-value (N = 579)

Variable	Privacy		Concentration		Communication		Social contact		Territoriality	
	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value	OR(CI 95%)	*P*- value
Desk location		**0.010**		0.066		**0.027**		0.141		**0.006**
0-2m	0.49 (0.28-0.85)	**0.011**	0.72 (0.41-1.26)	0.250	0.47 (0.26-0.82)	**0.009**	0.56 (0.27-1.15)	0.119	0.44 (0.26-0.75)	**0.003**
2-4m	0.40 (0.22-0.73)	**0.003**	0.49 (0.27-0.91)	**0.024**	0.48 (0.26-0.87)	**0.017**	0.47 (0.22-0.99)	**0.048**	0.43 (0.24-0.76)	**0.004**
Orienta-tion		**0.001**		**p < 0.001**		**0.034**		0.213		**0.007**
S.E	1.77 (0.92-3.43)	0.087	1.59 (0.82-3.05)	0.164	0.97 (0.50-1.85)	0.929	1.48 (0.65-3.40)	0.346	1.80 (0.95-3.41)	0.068
S.W	0.75 (0.42-1.31)	0.317	0.52 (0.30-0.91)	**0.024**	0.63 (0.37-1.06)	0.088	0.71 (0.39-1.30)	0.273	0.70 (0.41-1.2)	0.205
N.E	1.75 (0.99-3.10)	0.053	1.32 (0.76-2.31)	0.320	1.16 (0.66-2.02)	0.593	0.86 (0.45-1.62)	0.646	1.15 (0.66-2.00)	0.604
Layout		**p < 0.001**		**0.001**		0.463	-	-		**0.018**
Open	0.29 (0.17-0.49)	**p < 0.001**	0.37 (0.21-0.63)	**p < 0.001**	0.70 (0.42-1.16)	0.169	-	-	0.55 (0.33-0.90)	**0.019**
Combi	0.52 (0.25-1.08)	0.080	0.46 (0.22-0.99)	**0.047**	0.96 (0.46-1.97)	0.913	-	-	0.97 (0.48-1.98)	0.951
Flex	0.27 (0.15-0.50)	**p < 0.001**	0.33 (0.17-0.61)	**p < 0.001**	0.86 (0.48-1.54)	0.626	-	-	0.45 (0.25-0.81)	**0.008**
WWR	-	-		0.314	-	-		0.295	-	-
30%	-	-	0.89 (0.44-1.79)	0.748	-	-	0.67 (0.34-1.33)	0.257	-	-
50%	-	-	0.70 (0.44-1.10)	0.130	-	-	0.73 (0.47-1.14)	0.174	-	-
	R^2	0.129	R^2	0.120	R^2	0.050	R^2	0.040	R^2	0.081
	HL test	0.529	HL test	0.364	HL test	0.435	HL test	0.337	HL test	0.414
	Classifica-tion (%)	69.8	Classifica-tion (%)	68.0	Classifica-tion (%)	60.6	Classifica-tion (%)	75.4	Classifica-tion (%)	65.9

Note: B coefficients and odd ratios (95% CI) in bold highlighted are statistically significant ($p < 0.05$),
The results of Omnibus test are statistically significant ($p < 0.05$),
HL test refers Hosmer-Lemeshow test

FIG. 6.8 shows the most significant parameters of user's psychological satisfaction based on occupants' vote. In the questionnaire, 47.5% occupants responded 'having individual spaces for concentration' which was to be the most important aspect for their work environment followed by 'privacy'. On the contrary, 'social contact' was the least important aspect with 9.7% responses.

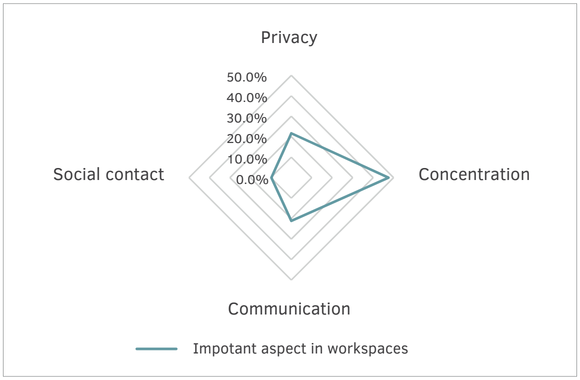


FIG. 6.8 Important psychological aspects in workspaces

6.8 Discussion

6.8.1 Design factors as predictors of occupant satisfaction

This chapter attempted to identify which design factors among desk location, layout, orientation, and WWR play a major role for the occupants' satisfaction with thermal, visual, and psychological comfort through user-based surveys and statistical analyses. As shown in TABLE 6.4 and 6.5, the occupants' satisfaction with thermal and visual comfort were statistically different according to the 'desk location', 'office layout', and 'orientation'. In contrast, WWR was not a statistically significant factor for thermal and visual satisfaction. The results from 579 office occupants showed that 'desk location' was the most influential factor to optimise IEQ satisfaction.

Desk location

Awada and Srour (2018) reported that employees who are close to a window tend to be more satisfied with IEQ conditions than those who are far away from a window. In contrast to their study, the results in this chapter showed that occupants who sit far away from windows tend to be more satisfied with environmental comfort compared to occupants who sit close to windows. Interestingly, there was no difference on the responses of satisfaction with thermal and visual comfort in different seasons. According to descriptive analysis, around 37% responded neither dissatisfied nor satisfied with thermal satisfaction, and over 60% for visual satisfaction in different seasons, followed by dissatisfied. In other words, people were almost equally responded their satisfaction in questionnaires. The outcomes in this chapter showed that workstations located close to windows have a bigger chance to be exposed to overheating indoor spaces due to the direct sun (Montazami et al., 2017) and unwanted illumination (Šeduikyte & Paukštys, 2008). Kamaruzzaman et al. (2015b) also revealed that thermal and glare level can be problems according to how close people sit to the window. Other reasons could be unoperable windows, positions of air inlets and outlets, and placement of radiators. However, these were not examined.

Orientation

Despite of the importance of design factors, few studies included ‘orientation’ as a design factor or a building feature in thermal comfort studies, since some studies stated that ‘orientation’ is not correlated to thermal comfort (Hua et al., 2014; Schakib-Ekbatan et al., 2015). On the other hand, Sadeghi et al. (2018) emphasised considering the influence of different façade orientations on visual preference. This research included ‘orientation’ as one of the design factors, and showed that the factor was comparatively less relevant to the satisfaction. However, the result in this chapter, showed that it was a considerably important factor for the satisfaction with thermal comfort in summer. Similarly, Konis (2013) suggested that ‘orientation’ has an impact on visual comfort, and people on the N.W zone were dissatisfied due to the direct sun and glare. Hua et al. (2014) stated that satisfaction with temperature is low regardless of orientations in both summer and winter. It means that orientation has no influence on the satisfaction with temperature. Instead, orientation contributed to the level of visual comfort with glazed façades. It is assumed that the existence of façade elements such as window blinds and management of the system could cause the different results.

Office layout

The findings in this chapter are consistent with an earlier study by Bluyssen et al. (2011), addressing that office layout has a primary impact on the comfort satisfaction in summer and winter. A study by Altomonte et al. (2019) revealed a strong correlation between spatial layout and workplace satisfaction and addressed that spatial design factors have a substantial impact on user satisfaction. The results related to layout are in line with the findings of Altomonte et al. (2016) and Shahzad et al. (2016), which revealed that IEQ satisfaction and thermal comfort are higher in cellular offices than open offices. It assumed that people have the high availability of thermal and lighting control in cellular offices than open offices.

6.8.2 Psychological satisfaction studies

As the categorical regression results have shown, office layout is absolutely important for user satisfaction. This research included four different layout groups, and the results were in line with the precedent research findings. In this research, open office was predicted to give higher satisfaction with territoriality than flex office, while flex office was predicted to give higher satisfaction in terms of communication than open plan office. This outcome supports the findings of Rolfö et al. (2018) and Gorgievski et al. (2010).

Rolfö et al. (2018) compared user satisfaction between open-plan offices and activity-based work places with flexi-desks, and observed different satisfaction rate according to the office types. Open-plan offices decreases user satisfaction in terms of privacy (De Croon et al., 2005; Kim & De Dear, 2013), and communication (Brennan et al., 2002). On the other hand, cellular offices showed good overall psychological satisfaction results. Aries et al. (2010) also reported that the best satisfaction results were found in cellular offices.

Combi and flex-office types were included additionally in this research. The probability of higher satisfaction was observed in combi-offices as well as cellular offices, as opposed to open and flex offices. It is assumed that combi-office has personal workstations, which can be shared with others, and meeting spaces for group/team work. Although the probability of user satisfaction in combi offices was not higher than for cellular offices, it was relatively higher than for open and flex-offices. De Been and Beijer (2014) revealed that occupants in combi-offices were more satisfied with communication than those in flex-offices. They argued that creating more chance to meet colleagues through the layout design does not lead to better communication. De Been and Beijer (2014) also reported that occupants in combi and flex offices were less satisfied with privacy and concentration than occupants in cellular and shared offices. In the result of the categorical regression analysis, users in combi-offices were more satisfied with communication than users in open and flex offices, which can partly support the results of De Been and Beijer (2014). Even though open-plan offices have been known as causing lower concentration, and more interruptions (Samani et al., 2017), occupants from open offices tended to be more satisfied with privacy, concentration, and territoriality than those working in flex offices. It is assumed that open offices allow occupants to have their own desks so that they were guaranteed territoriality. According to the regression analysis, 'office layout' did not significantly predict user satisfaction with communication. Nonetheless, the office users were found to be the most satisfied with the cellular office layout, followed by combi offices, the open plan office and lastly, flex offices.

'Orientation' was the second largest contribution factor to psychological satisfaction in. Nonetheless, there are few studies dealing with the association between façade/ workstation orientation and psychological satisfaction. Instead, there are many studies about orientation and visual comfort (Araji, 2008). Aries et al. (2010) tried to identify the impact of façade orientation on physical psychological discomfort, but orientation was ignored and combined in one group for their further research. One of the questionnaires in their research, was to examine the view quality. Users were supposed to answer whether they had good or bad outside view. They found that view quality influences employees' visual or psychological comfort, which was also confirmed by Tuaycharoen and Tregenza (2007). Even though the impact of orientation on psychological satisfaction has not been investigated yet, it can be explained that view/orientation may affect psychological satisfaction. Fabi et al. (2011) reported that users located towards the south façade would interact more with windows by opening and closing windows, and blinds. However, it does not mean that people were highly satisfied with the interaction. In this chapter, orientation greatly contributed to users' concentration on work. having a N.E orientation tended to be more satisfied than those working at the S.W. People working at the S.W showed least satisfaction with other psychological variables. Together with the findings of Fabi et al. (2011), the phenomenon can be explained by an assumption that as having more interaction with the façade causes low concentration of occupants on work.

How far people sit away from the window was not a significant predictor for territoriality, but it was a significant factor for the rest of the satisfaction parameters. Remarkably, 'desk location' gave the biggest effect on satisfaction with social contact. Although this research found that there was a relationship between desk location and psychological satisfaction, hardly any research has studied this association. Aries et al. (2010) used the same scale of parameters for desk location categories: 0-2m, 2-4m, and over 4m. The most frequent subject related to vicinity of the window is illuminance. For this reason, desk location was an important factor for the exposure of occupants to natural daylight or not. Escuyer and Fontoynont (2001) and Wang and Boubekri (2011) revealed that the desk location influences satisfaction with illuminance, and shows negative impact of desks close to windows on concentration. It is obvious that glare from direct sunlight causes occupants' visual discomfort (Inkarojrit, 2005). In line with the previous research, this chapter showed that the glare may not only decrease visual comfort but also disturb concentration on work. Although WWR was analysed to examine the impact of the natural daylight on psychological satisfaction, the 'WWR' was not a significant factor to predict any of the psychological satisfaction factors.

6.8.3 Statistical analysis

Evaluating users' comfort and satisfaction is complicated since it is difficult to interpret the results and to find a representative time and sample (Nicol & Wilson, 2011). Some studies used various statistical analysis to investigate the relationship between building characteristics and occupants' comfort or satisfaction. Factor analysis is often implemented for user studies to investigate variable relationships (Kamaruzzaman et al., 2015a; Veitch et al., 2007). In such a way, the analysis can reduce multi-collinearities and can group variables into statistically correlated groups (Flora et al., 2012; Sant'Anna et al., 2018). By performing the factor analysis, two underlying factors (thermal comfort and visual comfort) were proposed, which had bigger impact and could better explain occupants' responses towards environmental satisfaction. Similarly, a literature review defined occupants' comfort by four categories: thermal, visual, acoustic and indoor air quality (Antoniadou & Papadopoulos, 2017).

Later, we performed categorical and binary logistic regressions (Harrell, 2015). Frontczak et al. (2012) addressed that logistic regression can help to find the relative importance among IEQ parameters and building characteristics. Wong et al. (2008) examined IEQ parameters based on thermal comfort, air quality, acoustic comfort and illumination through a logistic regression model. However, the analysis can be used to predict the influence of design factors on user satisfaction. In this research, the CATREG was used before the logistic regression since the analysis can be implemented for a non-linear transformation of multiple (non-binary) dependent and independent variables to determine the logistic factors affecting dependent variables (Çilan & Can, 2014). The analysis uses optimal scaling method to assign numerical quantification to the categories of each variable (Meulman & Heiser, 1999). it contributes to narrowing the focus variables. Consequently, binary logistic regression used to verify the significance of each predictor with dummy variables and to prevent a multi-collinearity problem in the linear multiple regression model. Therefore, this statistical approach may provide an appropriate process for user-based studies in the indoor environment and draw general conclusions in the different work environment.

6.8.4 Low level of R2 value

The low R-square was observed in the outcomes of the regression analyses. R^2 indicates the percentage of variation in the independent variables, therefore the higher the R-square value is the better the explanation of the model. In general, an R^2 of 0.75 is strong, 0.5 is moderate, and 0.25 is weak (Wong, 2013). For that reason, some researchers interpret that the model is incomplete when the R^2 is lower than 0.25, although the relation is statistically significant. However, the low R^2, indicating the large spread of data explained by independent variables, is often presented in social science since human behaviour or satisfaction is difficult to predict (Frost, 2017).

Glenn and Shelton (1983) stated that eliminating the regression results with low R^2 is not appropriate in social research, instead, it is recommended to compare to other research. Moksony (1990) demonstrated that R^2 is not useful to compare either contribution of the independent variable or the goodness of the model fit; and suggested to use the unstandardized regression coefficient for the explanatory power and the standard error for the goodness of fit.

This chapter presented the percentage of cases correctly classified, which is one of methods to examine the predictive accuracy (Hosmer et al., 2013) and the Hosmer-Lemeshow analysis was used for the goodness of fit. The regression models had statistically significant explanatory power with between 60 and 70% of cases correctly classified, and the Hosmer-Lemeshow test showed higher than 0.05 in overall model coefficient. The range of the R^2 was from 5.6% to 14.2% in the categorical analysis, and from 5% to 12.9% in the logistic regression. A study about employees' discomfort by Aries et al. (2010) shows a similar range of R^2 (2% - 22%), and an outlier of 27%.

6.8.5 Limitations

The analysis compares one design parameter to each satisfaction variable. In reality, indoor climate is influenced by a combination of design factors, not one by one. Although certain design options showed a better outcome, it is necessary to consider the combination of a design option with other design options. Therefore, a limitation of this research is that it is difficult to say that the suggested design options will always lead to the best results in terms of occupants' satisfaction. Second, noise was excluded by factor analysis. Thus, noise needs to be studied separately from IEQ study. Last, the results to buildings located in other climates may lead to different conclusions. However, the study's approach can be used for different scenarios dealing with user studies. The findings may contribute to a user-focused office design during the conceptual design phases.

Four renovated offices and one non-renovated office were selected as case studies. This research included all collected samples for the statistical analyses, which could be a limitation of the study. The collected answers may be influenced by whether the office was renovated or not, since renovated offices are expected to have a higher environmental quality compared to non-renovated offices. In order to complement the issue that office renovation might affect the user satisfaction, the mean values of satisfaction were compared in FIG 6.1 and FIG 6.2. The result showed that there was no big difference, and the non-renovated office actually showed higher satisfaction level for some categories. Thus, all samples were included for further analyses. The scale of independent variables was recoded (e.g., satisfied, no satisfied) for the binary logistic regression. This is a common simplification to interpret being satisfied and not being satisfied instead of being dissatisfied.

This research intended to explore the indirect connection between the size of windows and psychological satisfaction. WWR was not a statistically significant predictor for the increase of satisfaction. The limitation of this research is that the research boundary condition was limited to the office design with physical design factors and socio-psychological aspect, which means that variables such as interaction with nature or view quality were not considered. Instead of including cognitive visual impact, it focused on the analysis of the individual and organisational level of satisfaction. Lastly, this research did not investigate the impact of psychological satisfaction on overall work/job satisfaction. However, it is obvious that lack of privacy and personal territory can cause overall dissatisfaction in workplaces (De Been & Beijer, 2014; Lansdale et al., 2011).

6.9 Conclusion

Office buildings have been mainly designed based on practical aspects following design guides. Design factors have not been tested by occupants' satisfaction. This chapter demonstrates influential design factors that can satisfy occupants' thermal, visual, and psychological comfort by focusing on architectural space and façade design. These design factors were evaluated by the user-focused subjective assessment in real office spaces. The subjective assessment by users was a useful method to evaluate design factors and its impact on the working environment. Satisfaction ratings provide the data on occupants' satisfaction and no satisfaction. In addition, the results clearly show that how well physical environments support the needs of the occupants.

The findings provide an insight into the relationship between design factors and user satisfaction in workplaces, and the attributes of design factors on thermal, visual, and psychological satisfaction. It also suggests the relative importance of each design factor, and the probability of increasing user satisfaction according to predictable design factors. This exploration of design factors, therefore, could play a crucial role to improve occupants' satisfaction and may suggest a new approach to office planning.

Following, prediction models were created through the logistic regression analysis. The planners and architects can consider the following suggestions:

- For the user satisfaction-related study, IEQ categories (e.g., temperature, humidity, air quality, lighting, daylight, view to outside, overall comfort) can be classified by thermal and visual comfort. However, acoustic comfort needs to be analysed separately from the IEQ satisfaction model, as acoustic comfort clearly did not load on any of the factors identified in the factor analysis.
- Office layout and desk location contribute most to thermal and visual user satisfaction, and layout, orientation, and desk location contribute to psychological satisfaction in workplaces.
- Despite the weak relevance of 'orientation' for thermal and visual comfort, 'orientation' can be a significant factor for thermal comfort in summer. Moreover, workspaces facing north-west and north-east are recommended to provide higher satisfaction with thermal comfort than other orientations. it is assumed that north-oriented workspace can avoid overheating during summer.

- With similar reasons, having distance from window for working desks can increase the level of satisfaction by preventing a sudden temperature difference and unwanted illuminance.
- In contrast, WWR may not affect occupants' satisfaction with thermal and visual comfort. However, it was one of the important factors having impact on energy savings.
- The same methodology can be applied to the user-related research. However, more complex models in which different design factors interact need to be explored for further research. Moreover, the results of predicted models can be tested in different climate zones.
- High levels of satisfaction corresponded to 'layout', except for variables of 'communication' and 'social contact'.
- Although the WWR was a significant predictor for satisfaction with social contact, the binary logistic regression showed that the factor was not statistically significant for predicting satisfaction.
- The probability of user satisfaction increased following the order of flex < open < combi < cellular office for privacy, concentration, and territoriality.
- The probability of user satisfaction increased following the order of 2-4m < 0-2m < 4m away from windows for privacy and territoriality, and 0-2m < 2-4m < 4m for communication.
- Users sitting at the N.W oriented workplace were more satisfied than those who sit at the S.W oriented workplace.
- The office design for the highest probability of users' satisfaction can be estimated to be a combination of N.W oriented workplaces, working desks located at least 4m away from the windows in a cellular office layout.

From an office organisational perspective, the conclusions in this paper may not directly give directions for the best office design to increase employee satisfaction, since the results focus only on occupants' psychological comfort. To give a complete picture, also criteria contributing to physical comfort should be included. Therefore, to develop a new design approach for office renovations, these results could be enhanced by including more satisfaction parameters. Nevertheless, this exploration of design factors could play a crucial role to improve occupants' satisfaction.

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