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User-focused design factors of workspace for nearly zero energy office renovation: findings from literature review

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Abstract

This paper highlights the importance of considering user satisfaction in office renovation. User-focused design approach in nearly zero energy office (nZEO) renovation is a way to increase user satisfaction and the value of office quality while meeting energy efficiency goal. The purpose of this paper is to investigate considerable measurement factors affecting user satisfaction. It is also to help better understating about user/occupants' preferences. Measurement factors are studied through literature reviews in relation to user satisfaction of workspaces. The approach aims to give a guide for analysis and evaluation of user satisfaction and to strengthen their importance in an office renovation. The findings present that main measurement factors to increase user satisfaction are not only associated with indoor environmental quality but also with psychological issues such as a feasibility of collaboration, social contact, etc. Additionally, the relationship between measurement factors and hierarchy of user requirements are described.

Keywords: *User values, occupant well-being, user satisfaction, office renovation, work environment*

1. Introduction

An awareness of healthy life has led to a concept of office design aimed to provide comfortable work environment and to make high quality workspaces. Management-oriented researches have addressed work environment by focusing on organisational structure and employee's performance (Danielsson and Bodin, 2008). This is because employees are likely to be motivated in better work environment.

Many studies have proven the correlation between better work environment and user satisfaction (Rothe et al., 2011a, Leifer, 1998, Wilkinson et al., 2011, Ornetzeder et al., 2016). At the same time, we all know we need to save energy and renovation of existing buildings is a potential solution to reduce energy consumption. In the European Union, around 85% of the 160 million buildings are showing thermally uneconomic conditions (SwedishScienceNet, 2010). According to EED (EU energy efficiency directive), the existing buildings have to be renovated within 30-40 years. Nearly zero energy office (nZEO) renovation can offer many opportunities in relation to reducing global energy use, reducing carbon footprint and, on a smaller scale, the energy bill. SHC (Solar Heating and Cooling) project reports state that building renovation can contribute to a 50-70% reduction in the overall energy demand (IEA, 2016).

However, does nearly Zero Energy Buildings (nZEB) provide a comfortable working environment to end-users? Nearly zero energy office renovation requires motivators other than energy saving benefits. In a functional perspective, nZEO renovations also have to provide a high level of comfortable work environment for employees' well-being and satisfaction besides realising a high energy reduction goal. A research addressed that indoor conditions may be connected to

employees' mental health (Houtman et al., 2008). Although recent researches have investigated the correlation between user satisfaction and Indoor Environmental Quality (IEQ), there are more measurement factors which need to be taken into account during a renovation plan. Existing satisfaction measurement methods pay less attention to the functional relationship between work patterns and user satisfaction in energy efficient buildings. Thereby there is a lack of user-focused design approaches or guidelines for office renovation.

User satisfaction can be determined by physical comfort and psychological comfort levels. For example, concentration, privacy, social contact with colleagues and work space responding to a collaborative work environment are more related to cognitive experience and psychological comfort. From this point of view, user satisfaction needs to be measured by psychological condition as well as physical condition.

Therefore, the aim of this paper is to identify measurement factors which have to be considered during the pre-design phase of nZEO renovation. The main research question that will be answered in this paper are: what are the initial factors to maximise user satisfaction of nZEO renovation? How can the user satisfaction level be measured and evaluated?

2. Literature review

2.1 An overview of the occupant satisfaction for workplace

2.1.1 Definition of the occupant satisfaction in workplaces

Occupants satisfaction is a quite intangible aspect. Van der Voordt (2003) defined that employee satisfaction is to meet the employees' preferences and needs in their working environment, and the increase of employee satisfaction level is caused by their physical and psychological comfort degree. The user needs are important elements for employees to perform well. On the other hand, the preferences are not a fundamental element for user satisfaction. However, if the workplace would be according to the preferences, occupants would show higher user satisfaction (Rothe et al., 2012). The majority of researches have investigated the relationship between environmental influences and occupants' well-being by focusing on the range from physical-related well-being such as indoor environmental quality (IEQ) (Levin, 2003, Humphreys, 2005, Mofidi and Akbari, 2016, Wargocki et al., 2012, Newsham et al., 2009) to psychological-related well-being. These factors are controlled by organizational management, employees' way of work described by work pattern, flexibility of workspaces and social interaction (Ekstrand and Hansen, 2016, Haynes, 2007, Ruostela et al., 2015, Harris, 2016). The influence of the office layout, ceiling height and openness (Vartanian et al., 2015, Danielsson and Bodin, 2008) also have been studied as a part of psychological parameters.

2.1.2 The importance of occupant satisfaction for user-focused design approach in workplaces

The level of user satisfaction has been emphasised by several researchers as a significant factor for successful sustainable buildings as well as conventional office buildings (Brown and Cole, 2009, Wilkinson et al., 2011). The traditional real estate supplier-driven business has been changed to a demand-driven business (Niemi and Lindholm, 2010). Thus, understanding users' needs and preferences is necessary to manage the demand side in office markets.

Furthermore, occupiers work environment satisfaction can reduce vacancy rates The real estate market has put an effort into attracting current and new tenants. Appel-Meulenbroek (2008) argued that real estate management needs to focus more on the current tenants' needs than on

potential new tenants' needs with several reasons:

- Keeping the current tenants' costs less than appealing to new tenants;
- The reduction of vacancy rate;
- The reduction of marketing cost;
- The reduction of operating cost.

As mentioned above, considering occupant satisfaction has a great impact on the organisational management of workspace.

2.1.3 Occupant preferences and expectations about workplace

Understanding occupants' preferences and their requirements for the work environment is a key driver to increase their satisfaction level and thereby adding value. IEQ and office design are the main elements which have an effect on the degree of user satisfaction. A preliminary study (Wilkinson et al., 2011) analysed parameters influencing user satisfaction in office buildings from various perspectives.
Table 1 summarises key categories from different studies influencing on the user satisfaction level.

From the employee's perspective, the interesting issues of nZEO buildings is well-being and health. The tenant is not interested in how much energy the building consumes and how much energy is saved. The employer or owner of a company rents an office because of its function and performance, supplying high quality work environment to employees. According to a survey (Rothe et al., 2011b), the most important attributes of the workplace are: functionality, comfort of the workspace, opportunities to concentrate and indoor climate. End-users want to work in a hygienic, comfortable and user controllable workplace where they can feel at home.

Another study about the user value of office buildings distinguished the meaning of well-being into psychological well-being and physical well-being. The concept of functional quality of buildings is divided into nine aspects: accessibility, parking facilities, efficiency, flexibility, safety, spatial orientation, privacy, territoriality and social contact, health and physical well-being, and sustainability (Van der Voordt and Wegen, 2005).

Besides the indoor quality of sustainable offices, building owners or tenants are also interested in the economical perspective. Building owners invest money for energy renovation, yet in the end the tenant pays the energy bill. Increased energy efficiency through nZEO renovation brings energy cost saving and provides financial benefits to users/tenants. Therefore, the prior requirements of office space for occupants define the physically and psychologically comfort, flexibility of workspace and efficiency.

Table 1 Criteria influencing user satisfaction in office buildings

References	User preferences/requirements factors																		
	Thermal comfort	Air quality	Noise control	Light /Daylight	User control	Spatial comfort	Privacy	Ability to do work	Concentration	Communication /Collaboration	Social contact /breakout space	Work location/ Flexibility	Ambiance	Aesthetic	Dimension work desk	ergonomics	Building location and amenities	View/ Scenery	Well-equipped facility
(Al Horr et al., 2016)	+	+	+	+			+					+		+			+		
(Ekstrand and Hansen, 2016)										+		+							+
(Harris, 2016)									+	+		+	+						
(Techau et al., 2016)		+	+	+	+								+					+	
(Ornetzeder et al., 2016)	+	+	+	+		+	+	+			+	+							
(Appel-Meulenbroek et al., 2011)	+				+	+	+				+	+	+	+	+	+			+
(Wilkinson et al., 2011)	+	+	+	+	+							+							+
(Rothe et al., 2011)	+	+	+	+		+	+	+	+	+		+	+				+		+
(Niemi and Lindholm, 2010)	+	+	+	+						+		+							+
(Oseland, 2009)							+		+	+	+	+						+	
(Danielsson and Bodin, 2008)					+		+		+	+	+	+							
(Haynes, 2007)	+		+	+			+		+	+	+	+		+					
(van der Voordt, 2004)	+		+	+					+	+	+	+	+					+	+
(Levin, 2003)	+	+		+	+														
(Leifer, 1998)	+	+	+	+		+	+	+				+							

2.2 The relationship between office layout and work pattern

Office layout has a strong interconnection with user satisfaction in a work environment. Modern office spaces are organised according to occupants' ways of working. This is the same for conventional offices layouts (Table 2), however the work pattern is getting divers.

In detail, organisations are changing and evolving. There are more team-based work and employees are physically more independent from their workspace than according to traditional workstyles. These changes brought the results of various strategies for workspace uses. The strategies basically stress that workspace should respond to workers' mobility (Table 3).

(Vos et al., 2000),(Dobbelsteen, 2004)		(Danielsson and Bodin, 2008)	
Cellular office	1-3 workplaces	Cell office	Single room office
Group office	4-12 workplaces	Shared room office	2-3 persons
Open-plan office	+13 workplaces	Small open plan	4-9 persons
		Medium-sized open plan	10–24 persons
		Large open-plan	+ 24 persons
Combi Office	Group work based	Combi office	Employees spend >20% of their time at workstations other than their own team-based work
Free office	Any place can turn into workspace	Flex office	No individual workstation The flex office includes backup spaces. Dimensioned for <70% of the workforce to be present simultaneously.

Table 2 Classification of office spatial concepts

Alternative workspace use strategy	Concept	Opportunities	Reference
NewWow (Multi-space use layout)	Comprehensive redesigning of work settings and practices (including physical, virtual and social working environment)	Space usage efficiency and costs dropped by 50%	(Ruostela et al., 2015)
Space-sharing structure	A workplace assigned to two or more employees, who use the workplace on a rotating basis	People always use the same space, giving employees sense of private territory	(Vos et al., 2000)
Non-territorial setting	A number of workplaces assigned to two or more employees Employees do not have their own territory	Provides opportunities for spontaneous interaction among employees Workgroups or departments are mobile, higher flexibility.	(Vos et al., 2000)
Activity-based setting	Workplaces are dedicated to specific tasks Employees move from one workplace to another depending on work activity Emphasizing mobility of employees	A more active approach to work, increased freedom and flexibility, better collaboration and cost savings due to less workplaces	(Vos et al., 2000)
Agile working	Workplaces emphasize mobility of workers within the office and outside of office.	Responding to flexibility, the choice of workers. Strengthening collaborative work and mobility.	(Harris, 2016)

Table 3 Alternative workspace use strategies

2.3 Measuring user satisfaction and measurement factors

2.3.1 User satisfaction measurement

Although measuring user satisfaction is complicated, it is imperative to develop a measurement method that can be applied to building design. Higher users' satisfaction can strengthen renovation design solutions and its total value (Shafaghat et al., 2016). Existing measurement tools mainly focusing on indoor environment of an office. It is considered as a healthy indoor environment when 80% of end-users are satisfied with the environmental settings (ASHRAEStandard, 2004).

Study	Title	Results	Tools
(Candido et al., 2016)	BOSSA: A multidimensional post-occupancy evaluation tool	Evaluation tool for nine indoor environmental quality dimensions and occupants' satisfaction	Building Occupants Survey System Australia (BOSSA)
(Kim and de Dear, 2013)	Workspace satisfaction: The privacy-communication trade-off in open-plan offices	Satisfaction level with workspace environment was the highest for those in enclosed private offices	indoor environmental quality (IEQ) dimensions
(Wargocki et al., 2012)	Satisfaction and self-estimated performance in relation to indoor environmental parameters and building features	Occupants in green buildings are on average more satisfied with their air quality and thermal comfort. Green offices prefer the spatial layout of open or partitioned floor plans to enclosed private offices.	LEED-rated/green buildings for indoor environmental quality (IEQ)
(Bluyssen et al., 2011)	Comfort of workers in office buildings: The European HOPE project	Perceived comfort is more than the indoor air quality, noise, lighting and thermal comfort responses. it also includes emotional state	Sir Karl Popper's theory model, Principal component analysis (PCA),
(Schakib-Ekbatan et al., 2010)	Occupant satisfaction as an indicator for the socio-cultural dimension of sustainable office buildings development of an overall building index	User satisfaction for comfort parameters at workplaces was affected by temperature, lighting conditions, air quality, acoustics, spatial condition and office layout	Principal component analysis (PCA), Post occupancy evaluation (POE)
(Veitch et al., 2007)	A model of satisfaction with open-plan office conditions: COPE field findings	18-item environmental satisfaction measure formed a three-factor structure reflecting satisfaction with: privacy/acoustics, lighting, and ventilation/temperature	Satisfaction with environmental features (SEF) measure
(Humphreys, 2005)	Quantifying occupant comfort: are combined indices of the indoor environment practicable?	Balanced occupants' satisfaction and overall assessments about indoor environment.	ASHRAE scale
(Leifer, 1998)	Evaluating user satisfaction: case studies in Australasia	User survey instrument based on nine parameters five grade scales regarding to user satisfaction	User satisfaction evaluation tool developed by Works Canada

Table 4 Summary of studies investigating parameters affecting user satisfaction and analysing tools

2.3.2 Physical factors

Thermal comfort

Thermal comfort is subjective and depends on dynamic factors made up of three variables: air temperature, relative humidity and relative air velocity (Hong et al., 2015). Although providing a

place where every occupant can be satisfied is impossible, it is important to define the thermal comfort level of occupants. Thermal comfort in an office can be measured by the number of discomfort complaints from occupants (Al-Horr et al., 2016). A laboratory study (Lan et al., 2012) examining the effect of operative temperature on relative work performance shows that in summer, the indoor temperature for optimum performance can be increased from 23.9 to 25.4°C. In winter the indoor air temperature for optimum performance can be decreased from 21.9 to 19.7°C. Another laboratory study of (Tham and Willem, 2010) tested thermal comfort level and time exposure of occupants in three different room conditions. The result is thermal comfort is the highest at the 23°C condition. Two studies (Lan et al., 2012, Tham and Willem, 2010) proved that the preferred indoor air temperature level for occupants' comfort is regardless of energy efficiency considerations.

Air quality

A work place with good air quality has an impact on occupants' health condition and their satisfaction rate. IAQ studies have found these issues by conducting questionnaire about irritation, headaches, fatigue and illness, which are related to Sick Building Syndrome (SBS) symptoms (Seppänen et al., 2006, Wargocki et al., 2000). Better indoor air quality also reduces the health risks of occupants and increases productivity (Lan et al., 2011). Indoor air quality can be controlled by the ventilation rate and high ventilation rates result in a good indoor air quality. It means that Indoor Air Quality (IAQ) rate is assessed by the ventilation rate.

A ventilation system for a building should be selected based on building types and occupant behaviour patterns and expectations (Kim and De Dear, 2012). There are different ventilation systems which include a natural ventilation system or a hybrid/mixed mode HVAC system. The mixed mode HVAC system has a higher satisfaction rate and energy savings than other mechanical systems (Ezzeldin and Rees, 2013). In order to investigate the interrelation of air quality and satisfaction level, occupants' perception survey should include illnesses and SBS symptoms in their work place. These results will lead to better understanding IAQ condition and influence of user satisfaction.

Noise control

Noise has a high relevance in office building design. The effect of noise can lead to distraction and interruptions in workability of occupants. Noise in the office normally comes from colleagues and it often occurs in the open-plan office (Ornetzeder et al., 2016). Noise performance is also related to privacy in this case. A recommended minimum background noise level for open-plan offices is 45 dB, for cellular offices 40 dB (Field, 2008). In European standards, the level for the cellular office is from 30 to 40 dB and for the open-plan office is from 35 to 45 dB.

Light and daylight

The light condition is one of the factors that gives an influence on user satisfaction in their work place. The reason is that daylight has an impact on human visual comfort. The majority number of office employees prefers natural light over artificial light (Galasiu and Veitch, 2006) because of physical and psychological reasons. A research (Villa and Labayrade, 2016) aiming for energy-efficient luminous environment identified the optimal solution to be suitable for different users' requirements. The solution is to supply an individual task lamp which does not have a high-power demand (11W each) in shared office spaces.

The choice of window and shades system, in this point of view, is an important factor. It is not only because of providing outdoor views but also serving natural light. Preferred window size varies for different office conditions; however, a survey (Galasiu and Veitch, 2006) stated that the optimal window size on average needs to be in the range of 1.8 to 2.4 m in height to provide a

wide lateral view.

2.3.3 Psychological factors

User control
Personal control for indoor environment is highly likely to improve user satisfaction level. A research stated that when office workers can control their own indoor environment comfort, health are improved (Raw et al., 1990). On the other hand, from an economic perspective, user control can result in a waste of energy due to inefficient thermal control (Shahzad et al., 2016). There are different employee groups in an office according to their various tasks and they have different work patterns. These conditions affect different building operational patterns. In other words, it is necessary to find out what are the optimal points of IEQ level for various occupant types and the optimal operational strategy will be the key to catch two goals.

Privacy
Privacy has a close relationship with office layout. The privacy of office workers is better protected in an individual space than in an open plan office. Privacy is distinguished by physical and cognitive aspects; sound privacy, visual privacy and perceived privacy, experienced by uncontrolled social contact and interruptions (Kim and de Dear, 2013). Specifically, the open-plan office has poor privacy conditions. However, it cannot be said that the open-plan office is highly likely to have privacy problems: it depends on the density of workstations. A larger workstation in open-plan office increases the satisfaction rate with acoustics and privacy (Leder et al., 2016) because the distance between colleagues is much greater. In terms of job satisfaction, privacy is related to more psychological demand which can lead to a higher level of cognitive satisfaction.

Spatial comfort
Spatial comfort is one of the key factors that determines to which extent workers would be satisfied and motivated in their workplace (Chandrasekar, 2011). Although this is a quite subjective factor, it is worthy to note for office design. Reasons for this is that several studies have revealed that office workers who feel comfortable with their work environment tend to show better work result and have relatively high self-esteem (Leder et al., 2016, Lee and Brand, 2005, Salama and Courtney, 2013). The awareness of spatial comfort is also associated with the organisation of workspace. One of the significances of office functionality is flexibility. With going along the lines of the view, a survey has revealed almost 90% of the respondents answered that better workplace layout and functional support result higher overall workers' performance (El-Zeiny, 2012, Gensler, 2006). Through other studies, it is identified that spatial comfort is determined not only by thermal conditions, light and acoustics but also by workplace design and layout.

Concentration
Concentration level is one of the major requirements for improving user satisfaction (Rothe et al., 2011b) and it is emphasised for the impact on users' task performance. Concentration is disturbed by different elements: air quality, loud noise, conversation and glare. These are physical elements. In the work environment, concentration is a significant factor for a worker who has more single-oriented work task.

Communication/collaboration
Improvement of the communication level is likely connected to productivity. It is because of better information exchange between colleagues and having more contact provides more understanding of each other (Van der Voordt, 2003). This factor is decided by the office layout and operational conditions.

Social contact
Establishing social contact is one of the factors to satisfy user demands. The definition of social contact here means interacting with other people to take a break or to have a chat. This parameter is highly linked to office layout and workspace operation.

2.3.4 The relationship between measurement factors and user requirements

Many studies mixed physical quality and psychological or cognitive quality of user satisfaction. In order to assess the level of user satisfaction, the measurement factors will be divided into three categories; basic human needs/must-be requirements, psychological needs/one-dimensional requirements and self-fulfilment needs/attractive requirements (Maslow, 1943, Witell et al., 2013, Shafaghat et al., 2016).

Maslow's Hierarchy of Needs (Maslow, 1943) depicts the user needs in three categories: basic needs, psychological needs and self-fulfilment. In overview of Maslow's model, the user needs can be divided into two parts: physical basic needs and psychological needs. Other studies demonstrated that satisfaction levels can be divided into three levels: necessity (basic satisfaction), performance (moderate satisfaction), and happiness (superior satisfaction) (Mbachu and Nkado, 2006, Wilkinson et al., 2011). These ways of grouping are quite similar to the Kano method (Witell et al., 2013). These humanistic concerns can be applied in conceptual design process and should not be ignored in the earliest design stage (Zhao et al., 2015).

3. Reflection and conclusion

3.1 Conclusions/findings

The findings from this paper highlight the importance of user satisfaction in office renovation, and functional requirement of nZEO renovation. The relationship between physical and psychological functionality of offices and 10 factors of user satisfaction have been analysed as shown in Figure1.

Physical conditions in workspaces such as heating, cooling, ventilation, light and noise are fundamental requirements for users. The parameters also have a strong connection with energy consumption. Besides the fundamental human needs, office occupants tend to seek to have cognitive/psychological comfort for better work environment. These factors lead to a higher-level of user satisfaction.

The level of user satisfaction is highly connected to the following ten parameters, and overall satisfaction is added to prevent missing indicators in case:

- Thermal comfort
- Air quality
- Noise control
- Light
- User control
- Privacy
- Spatial comfort (open space design and flexibility)
- Concentration (ability to do your work)
- Communication with their colleagues/work groups
- Social contact
- Overall satisfaction

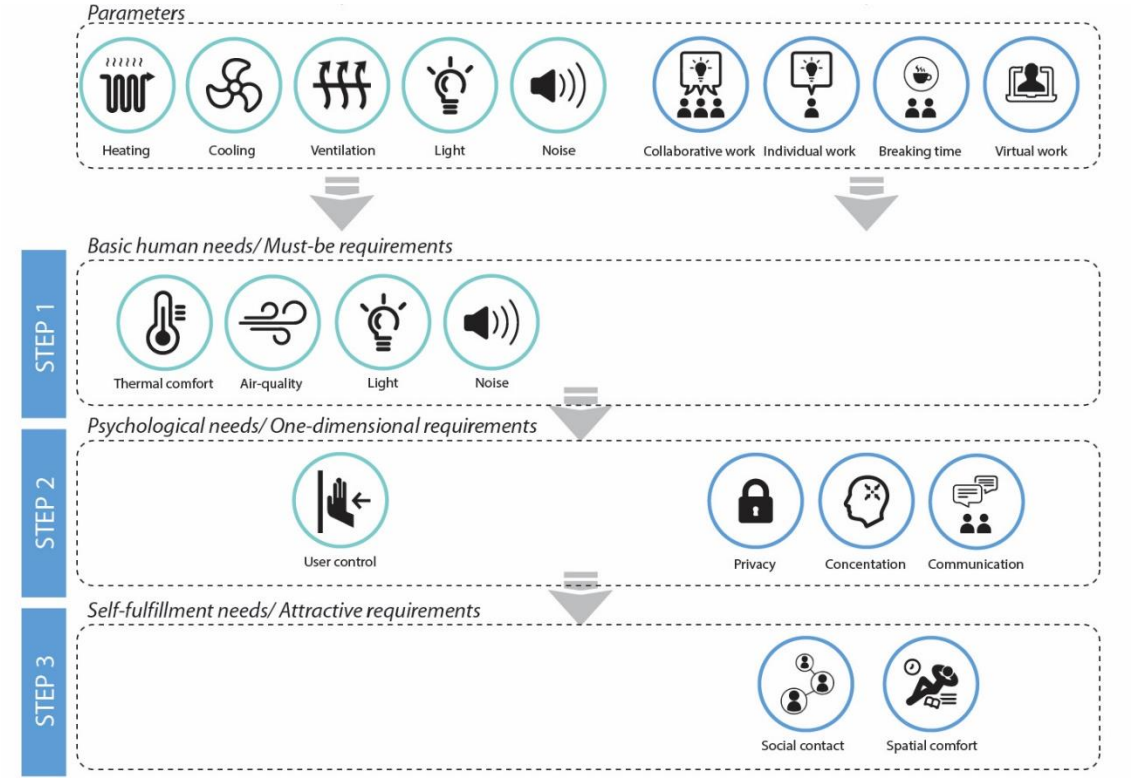

Figure 1 Classification of parameters for user-focused design

3.2 Discussion

In this paper, the measurement factors, used in other studies, to increase user value and satisfaction have been classified and analysed. In terms of indoor quality of offices, thermal comfort, air quality, light and noise are the most important factors. In addition, user control is also concerned as one of the important factor in relation to cognitive aspect. Although many researches deal with flexibility of workplace, in detail, the flexibility is highly related to communication/ collaboration. The factors such as privacy, concentration and social contact are also essential factors to achieve higher user satisfaction. It is important to consider how to measure the factors and how to evaluate user satisfaction. Particularly, cognitive-related factors such as social contact and spatial comfort are subjective so that the result might only rely on the user opinion. One possible method to study these cognitive related factors, is by using a questionnaire to conduct a survey. However, the quantitative data still need to be investigated, in order to find out whether they are essential factors for office renovation or not.

The definition of user satisfaction in this paper is different from job satisfaction of employees. Job satisfaction often include emotional aspects from having good working relationship with a boss or a leader or colleagues. This job satisfaction, however, is not part of the user-focused renovation design approach.

3.3 Recommendations and outlook

Some limitations may be related to evaluating user satisfaction and interpreting the results of collected data. For the further quantitative research, a questionnaire should be strongly connected to each measurement factor. As a result, the questionnaire needs to show each factor can potentially support users' requirements. The results of this paper provide important parameters for user-focused office renovation and strengthen the cogency of user requirements associated

with office renovation.

The correlation between measurement factors and user-focused design strategies has to be studied. Likewise, the strategies to increase user satisfaction should be studied more in-depth. The next step in this research will be to look at the direct and indirect influences of user-focused design factors on nZEO renovation design strategies.

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