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User-focused office renovation: a review into user satisfaction and the potential for improvement

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Abstract

Purpose – This paper highlights the importance of user satisfaction in office renovation. A user-focussed renovation approach can enhance user satisfaction in offices and their functional quality while meeting energy performance goals. The purpose of this paper is to investigate users' needs and the physical and psychological factors affecting user satisfaction, as input to office renovation projects.
Design/methodology/approach – The selected articles are collected from Scopus, ScienceDirect and Google Scholar. Searching was limited to the main key terms of office, work environment, and user satisfaction and comfort. The important factors were searched through empirical-based international literature mainly. Based hereupon, a guide will be developed for the analysis and evaluation of user satisfaction in office renovations.
Findings – From a comprehensive overview, the findings present ten main factors to increase user satisfaction in office renovation. These are associated with physical and psychological satisfaction and comfort. In addition, the influential factors were categorised into three levels based on needs theories to organise the hierarchy of priorities.
Practical implications – This research adds to the body of knowledge about which factors are important for user satisfaction, based on what previous research has found in that field. This is important to improve the sustainability in use.
Originality/value – User satisfaction is often studied through separate aspects: health and indoor climate vs functionality and productivity. This paper examines overall user satisfaction of workplaces by integrating the perspectives of physical and psychological conditions, and by providing insight into the priority of satisfaction factors.

Keywords User satisfaction, Work environment, Occupant well-being, Office renovation, Workplace management

Paper type Research paper

1. Introduction

Awareness of healthy living has led to a concept of office design aimed to provide a comfortable work environment and to make high-quality workplaces. According to the European "Energy performance of Buildings Directive", new energy-efficient buildings

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should secure occupants' comfort and high satisfaction in both physiological and psychological ways to increase productivity (Wagner *et al.*, 2007). It means that new building concepts should be developed to meet the occupants' comfort standard.

Some studies stated that green building offices lead to greater productivity, lower absence and happier employees (Armitage *et al.*, 2011; Liang *et al.*, 2014; Abbaszadeh *et al.*, 2006). In contrast, others argued that there is no significant relationship between green buildings and the occupants' satisfaction with Indoor Environmental Quality (IEQ) or that the influence is quite small compared to conventional offices (Thatcher and Milner, 2012; Paul and Taylor, 2008). Leaman and Bordass (2007) and Gou *et al.* (2013) also concluded that the indoor environment of green buildings was not always performing highly, but that users tended to be more tolerant in green buildings. Other research of Liang *et al.* (2014) explained that occupants were more tolerant with IEQ when concerning energy consumption. These studies proved that green buildings, such as LEED or Green Star certified buildings do not always support a high level of user comfort and satisfaction.

Therefore, the question that this study considers is: does a high energy performance office provide end-users with a comfortable working environment? At present, building designs or renovation processes mainly focus on practical aspects such as energy performance, aesthetical aspects, cost optimisation and fundamental indoor quality by complying with the building regulations. However, office renovation also has to provide a high-level comfortable work environment for the occupants' well-being and satisfaction besides maximising energy reduction goals. Furthermore, a user-focussed design approach or guideline for office renovation is lacking.

User satisfaction has been emphasised by several researchers as a significant factor for successful sustainable buildings (Rothe, Lindholm, Hyvnen and Nenonen, 2011; Leifer, 1998; Wilkinson *et al.*, 2011; Ornetzeder *et al.*, 2016). van der Voordt (2004) stated that satisfaction can be related to the work itself, the social environment, the physical environment and interactions among them. Haynes (2008) narrowed down the occupants' satisfaction to the physical environmental scale. According to him, user satisfaction can be measured by how comfortable occupants feel in their environment. The author also found that employees' productivity became low when they are physically uncomfortable.

An empirical research of Fisk (2000) revealed that there is no direct association between high indoor comfort and high productivity. On the other hand, several researchers have revealed the relationship between healthy buildings and employees' productivity (Abbaszadeh *et al.*, 2006; Singh *et al.*, 2010; Heerwagen, 2000), and the significance of IEQ impact on user satisfaction in green buildings (Altomonte, Saadouni, Kent and Schiavon, 2017). Houtman *et al.* (2008) addressed that indoor conditions may be connected to the mental health of building users.

The aim of this paper is to identify the influential factors that have to be considered to increase user satisfaction in workplace. The outcome proposes ten physical and psychological parameters for user satisfaction. It also suggests the hierarchical priority structure based on the needs theory: basic, proportional, and bonus factors. Integrating a user satisfaction approach for workplaces in energy renovation projects is a challenge in both building engineering and building management fields. Thereby, the advanced user satisfaction approach is at the cutting edge of research in the built environment. The main research questions that will be answered in this paper are:

RQ1. What are the initial factors to maximise user satisfaction?

RQ2. How can the order of priority of influential factors be determined?

RQ3. How are the influential factors related to energy efficiency?

2. Methodology

This paper presents an international literature review on user satisfaction of workplaces with the aim to apply the findings to energy-efficient office renovations. The key search terms for the literature study focussed on work environment including "office renovation", "user satisfaction", "comfort", "wellbeing", "work environment", "workspace" and "workplace", "energy efficiency" and "green building". The search was carried out by using the online journal article databases: Scopus, ScienceDirect and Google Scholar. Table I shows the keywords used for searching journal and book databases. In order to select only office related user satisfaction, some keywords were used to sort out unrelated field information such as hospital, school, house, housing, systems, software, network, infrastructure and city grid.

From Scopus, only 12 documents were found. Three journal articles dealt with these topics from 1989 to 1999, and nine articles were found from 2000 onwards. In total, 77 articles were found from 2001 onwards via ScienceDirect. Google scholar was used to limit missing information as a result of excluding some keywords. The results from the literature search showed that the topic first gained interest after 2000, and so the literature review was limited to the period 2000–2018.

The scope of this paper includes the most influential factors in workplace environment and office renovation that were determined in studies during the previous two decades. A total of 124 papers were referenced as main input to analyse the relationship between the two fields. The finding intersections approach (Ridley, 2008) was used for the literature review of this paper (see Figure 1). This approach helps to define the gap and overlapping

Search keywords	
AND	(Work environment or office or workplace or workspace)
	(User satisfaction or comfort or well-being)
	(Office renovation or energy efficiency or green building)
AND NOT	(Hospital)
	(School building or educational building)
	(Housing or house)
	(Systems or software or network or infrastructure)
	(City grid or urban structure)

Table I.
Keywords used for journal article searches

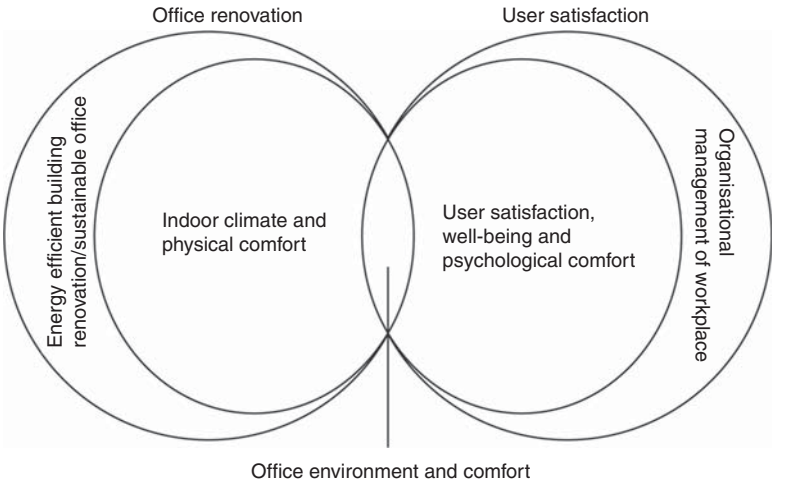

Figure 1.
Literature review approach

issues between office renovation and user satisfaction, showing how each field has been developed separately, and where intersection is found.

The literature selected was classified into five categories (see Table II). Literature was prioritised based on these categorised keywords. Literature was reviewed on energy-efficient building renovation and user satisfaction as main areas. Figure 1 presents the intersection from the literature approach and keywords identifying overlapping and separated subject fields. However, user satisfaction and well-being has been a major consideration.

3. Literature review

3.1 Energy-efficient office renovation and user satisfaction

Building renovation technologies mainly deal with energy efficiency and high-quality indoor environments. However, human comfort is often overlooked in sustainable building design principles (Shahzad *et al.*, 2016). Energy-efficient buildings are often regarded as comfortable and healthy buildings because of improved indoor environmental quality (Krarti, 2018; Leaman and Bordass, 2007). Lower environmental impact or green buildings scored better on indoor environment and comfort (Leaman and Bordass, 2007). Nonetheless, building energy research shows a conflicting issue between energy saving and optimisation of indoor comfort (Shaikh *et al.*, 2014; Lu *et al.*, 2017). It is a big challenge to include office users in a renovation design process due to many uncertainties, such as service change and various human behaviour, which can directly affect the selection of renovation technologies (Ma *et al.*, 2012; Allouhi *et al.*, 2015). Besides, there are many factors with significant impact on the sustainability of a building, for instance, the building envelope, building elements and building services (Jensen *et al.*, 2013; Bruel *et al.*, 2013; Iwaro and Mwasha, 2013). Similar studies also found barriers regarding the relationship between economic issues and building property value (Newell *et al.*, 2011; Kok and Jennen, 2011, 2012; Chegut *et al.*, 2014; Allouhi *et al.*, 2015). Most of the studies mentioned above stressed the importance of standard renovation methods that can provide guidelines for user-focussed building renovation.

From a functional point of view, the main concept of the office design is becoming more focussed on the occupant's satisfaction and preferences. At the same time, the concept of office design has changed due to the various working patterns with the advancement of ICT. Studies have proved that a high quality of the physical environment is directly connected to employee satisfaction (Veitch *et al.*, 2007; Wells, 2000) and productivity (Tucker and Smith, 2008; Maarleveld *et al.*, 2009; Wilkinson *et al.*, 2011; Al-Horr *et al.*, 2016) Other studies have investigated the relationship between sustainable office buildings and workspace environment (Arge, 2005; Dobbelsteen, 2004; Wilkinson *et al.*, 2011), and the well-being and health of occupants and office design (Leder *et al.*, 2016; Newsham *et al.*, 2009; De Croon *et al.*, 2005).

In those findings, the physical working environment (e.g. the organisational plan and IEQ) and user comfort are interlinked to satisfaction, and these perspectives need to be considered for office renovation. Thus, three concepts for the sustainable office plan can be defined: high functionality for occupants, renovation strategies for energy efficiency and user satisfaction.

Keywords	Number of literatures
Energy-efficient building renovation/sustainable office	39
Organisational management of workplace	36
User satisfaction, well-being and psychological comfort	58
Indoor climate and physical comfort	25
Office environment and comfort	31

Table II. Summary of keywords from selected journal articles

3.2 An overview of the occupant satisfaction of workplaces

3.2.1 Definition of the occupant satisfaction of workplaces. Occupant satisfaction is quite intangible. Huber *et al.* (2014) alerted that a general overview of user satisfaction and influencing factors in building design research is lacking. Moreover, it is difficult to define the term of user satisfaction, since there is no standardised measurement method for user satisfaction. van der Voordt (2003), however, defined that employee satisfaction is improved by meeting the employees' preferences and needs in their working environment, and the increase of the employees' satisfaction level is caused by their physical and psychological comfort degree. Shaikh *et al.* (2014) stated that comfort is the condition of mind influenced by psychological effects and is coherent with satisfaction of the environment. Their definitions show that the occupants' preferences are important elements for them to be satisfied and perform well. Rothe *et al.* (2012) also agreed that when the workplace condition meets the occupants' preferences, they show higher user satisfaction. Other research of Rothe, Lindholm, Hyvnen and Nenonen (2011) summarised the concepts of user needs, preferences and requirement based on literature (see Figure 2). Basic psychological needs, such as comfort, safety, sense of belonging and security, are required for people to perform well and maximise their potentials.

The majority of scholars have explored the relationship between environmental influences and occupants' well-being by focussing on the range from physical-related well-being, such as 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 organisational management, the employees' way of working as 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 elements.

3.2.2 Occupant preferences and expectations of the workplace. Understanding occupants' preferences and requirements in working environment is a key driver to increase their

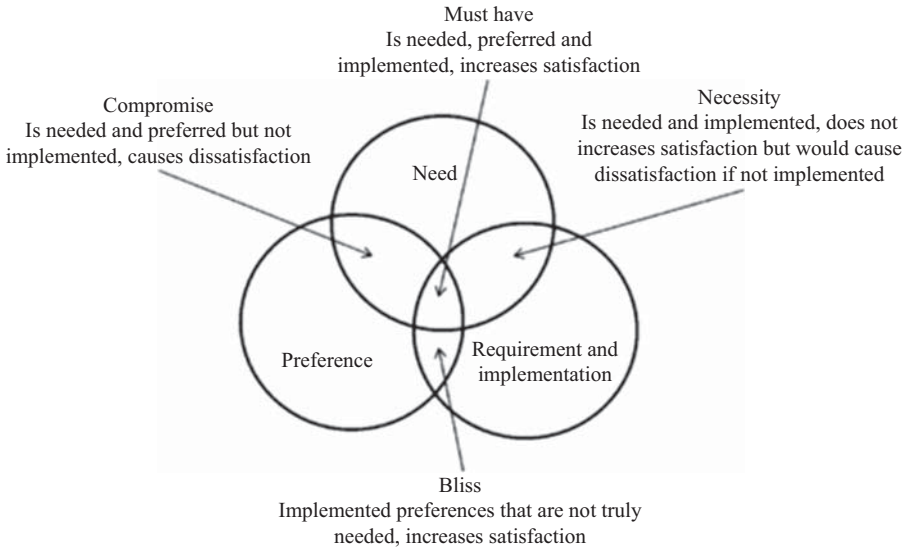

Figure 2.
The relationship between the concepts need, preference, and requirement and implementation

Source: Rothe *et al*. (2010)

satisfaction level. IEQ is the main element which has an effect on the degree of user satisfaction (Frontczak *et al.*, 2012; Bluyssen, 2013). A preliminary study of Wilkinson *et al.* (2011) analysed parameters influencing user satisfaction in office buildings from various perspectives. The author revealed that there was a big gap between user satisfaction and expectations in individual control of environmental quality. Moreover, IEQ factors such as temperature, ventilation, heating, cooling and lighting were the most problematic issues because the indoor condition does not qualify occupants' expectations.

From the employee's perspective, the interesting issues of office renovation are well-being and a healthy work environment (Leather *et al.*, 2003). Employees want to work in a hygienic, comfortable and user controllable workplace where they can feel at home (Naccarella *et al.*, 2018). Another study about the user value of office buildings distinguished the meaning of well-being into psychological well-being and physical well-being. van der Voordt and Wegen (2005) defined the concept of functional quality of buildings with nine aspects: accessibility, parking facilities, efficiency, flexibility, safety, spatial orientation, privacy, territoriality and social contact, health and physical well-being, and sustainability.

Table III shows the most frequently mentioned factors with a significant impact on user satisfaction, according to the selected literature from the last 20 years. The literature was selected based on keywords: occupants (user) satisfaction, comfort/well-being, indoor climate and comfort, energy-efficient building renovation.

Many studies of Haynes (2007), van der Voordt (2004), Rothe, Lindholm, Hyvnen and Nenonen (2011), Appel-Meulenbroek *et al.* (2011), Wilkinson *et al.* (2011), Techau *et al.* (2016) and Ornetzeder *et al.* (2016) cover a wide range of user requirements contributing to satisfaction, ranging from physiological and psychological to social aspects. Rothe, Beijer and van der Voordt (2011) and Al-Horr *et al.* (2016) included additional factors such as building location and amenities as factors that attribute user preferences. Kim and de Dear (2013) conducted survey based on various parameters that are not only physical and psychological conditions but also ergonomics and office equipment (see Table III). The main conclusion was that spatial configuration has a significant influence on physical and psychological satisfaction.

Harris (2016), Oseland (2009) and Danielsson and Bodin (2008) focussed on psychological aspects of user requirements such as interaction with colleagues, privacy and outside scenery. Interestingly, the researchers connected these preferences to office types and organisation. Choi and Moon (2017) revealed that environmental satisfaction is influenced by the location of the workstations. Liu *et al.* (2018), Choi and Moon (2017), Baird *et al.* (2012) and Levin (2003) studied the relationship between user satisfaction and indoor environmental parameters. Levin (2003) emphasised that user control over indoor environment is essential to increase the level of user satisfaction. Pathak *et al.* (2014) observed in an empirical study that thermal, lighting and spatial arrangements are the most important parameters for users' comfort, satisfaction and efficiency.

Based on Table III, the top ten factors for measuring user satisfaction level according to the literature were selected: thermal comfort, air quality, noise, light, user control, privacy, spatial comfort, concentration, communication/collaboration and social contact. Indoor climate and physical comfort are significantly related to each other. Many studies deal with the topic. On the other hand, organisational management of workplace strongly influences psychological comfort of employees.

3.3 Measuring user satisfaction and measurement factors

3.3.1 User satisfaction measurement. Although measuring user satisfaction is complicated, it is imperative to develop a measurement method that can be applied to building design. A higher user satisfaction can strengthen renovation design solutions

Table III.
Criteria influencing user satisfaction in office buildings

References	User preferences/requirement factors									
	Thermal comfort	Air quality	Noise control	Light/ daylight	User control	Spatial comfort	Privacy	Ability to do work	Concentration	Communication/ collaboration
Liu *et al.* (2018)	+	+	+	+	+		+			+
Altomonte, Schiavon, Kent and Brager (2017)	+	+		+	+	+				
Choi and Moon (2017)	+	+	+	+		+	+			
Al-Horr *et al.* (2016)	+	+	+	+		+	+			
Harris (2016)									+	+
Techau *et al.* (2016)		+	+	+	+					
Ornetzeder *et al.* (2016)	+	+	+	+		+	+	+		
Pathak *et al.* (2014)	+			+		+				
Kim and de Dear (2013)	+	+	+	+		+	+			+
Baird *et al.* (2012)	+	+	+	+	+					
Appel-Meulenbroek *et al.* (2011)	+				+	+	+			
Wilkinson *et al.* (2011)	+	+	+	+	+					
Rothe, Lindholm, Hyvnen and Nenonen (2011)	+	+	+	+		+	+	+	+	+
Niemi and Lindholm (2010)	+	+	+	+						+
Oseland (2009)							+		+	+
Danielsson and Bodin (2008)					+		+		+	+
Haynes (2007)	+		+	+			+		+	+
van der Voordt (2004)	+		+	+			+		+	+
Levin (2003)	+	+		+	+					
Total	15	12	12	15	8	8	11	2	6	9

(*continued*)

References	Social contact	Work location	Ambience	Aesthetic	Dimension work desk	Ergonomics	Building location/ amenities	View/ scenery	Well-equipped facility
Liu *et al.* (2018)									
Altomonte, Schiavon, Kent and Brager (2017)		+						+	
Choi and Moon (2017)								+	
Al-Horr *et al.* (2016)		+		+			+		
Harris (2016)		+	+						
Techau *et al.* (2016)			+					+	
Ornetzeder *et al.* (2016)	+	+							+
Pathak *et al.* (2014)		+							
Kim and de Dear (2013)		+			+	+			+
Baird *et al.* (2012)									
Appel-Meulenbroek *et al.* (2011)	+	+	+	+	+	+			+
Wilkinson *et al.* (2011)		+							+
Rothe, Lindholm, Hyvnen and Nenonen (2011)		+	+				+		+
Niemi and Lindholm (2010)		+							
Oseland (2009)	+	+						+	
Danielsson and Bodin (2008)	+	+							
Haynes (2007)	+	+		+					
van der Voordt (2004)	+	+	+					+	+
Levin (2003)									
Total	6	14	5	3	2	2	2	5	6

Table III.

and the building's total value (Shafaghat *et al.*, 2016). Post-occupancy evaluation (POE) has widely been used to evaluate building performance (Göçer *et al.*, 2015). This method is also applicable for user's well-being and satisfaction with renovation projects (Al-Horr *et al.*, 2016). Existing measurement tools mainly focus on the indoor office environment. Table IV shows literature on user satisfaction parameters as well as on analytical measurement tools. It also highlights that POE is a common method to collect real-time data. POE uses three different tools, questionnaires and interviews, bills and metrics, and physical measurements by using sensors. Green buildings are considered healthy indoor environments when 80 per cent of the end-users are satisfied with the environmental settings (ASHRAEStandard, 2004). However, in a recent study, Loftness *et al.* (2018) designed a new framework for evaluating building performance and POE, based on spatial, thermal, air, acoustic, visual and building integrity.

3.3.2 Classification of parameters affecting user satisfaction. Many studies mixed physical quality and psychological or cognitive user satisfaction by using a cause and effect

Study	Title	Results	Tools
Loftness *et al.* (2018)	Critical frameworks for building evaluation: user satisfaction, environmental measurements and the technical attributes of building systems (POE + M)	POE+M helps occupants and managers to understand the impacts of work environments on health and productivity; to analyse building systems for IEQ	Post Occupants Evaluation and Measurements (POE + M), National Environmental Assessment Toolkit (NEAT)
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)
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 IV.
Summary of studies investigating parameters affecting user satisfaction

analytical approach. The approach basically analyses measurable human behaviour and satisfaction based on physical conditions (Vischer, 2008a). However, perceived satisfaction is more than physical conditions (Bluyssen *et al.*, 2011). Therefore, it is important to develop a theoretical framework to determine the order of priority or the degree of importance among factors influencing user satisfaction.

From an architectural point of view, Vischer (2008a) illustrated a form for assessing user experience including three comfort levels: physical comfort, functional comfort and psychological comfort, and how well the office provides effective and comfortable workplaces to users. Feige *et al.* (2013) redefined the dimension of comfort factors with three levels: physical comfort relates to biological responses to indoor quality, climate, noise and ergonomics; functional comfort refers to the suitability for work tasks; and psychological comfort indicates space-related needs such as social and spatial variables. Kim and de Dear (2012) classified the dimensions of comfort into three categories: basic factors can cause dissatisfaction when they are not fulfilled; proportional factors can change the satisfaction level proportionally; and bonus factors that, although showing poor performance, do not result in dissatisfaction. The classification of Kim and de Dear (2012) is similar to the Kano (1984) model.

3.3.3 Physical comfort factors. Physical factors were selected based on the relationship with biological responses to indoor climate and quality. Those factors are basic needs that may cause severe dissatisfaction and illness.

Thermal comfort. Thermal comfort is subjective and depends on dynamic factors consisting of four variables: air temperature, relative humidity, relative air velocity and radiation (Hong *et al.*, 2015). Although providing a place where every occupant can be fully satisfied is practically impossible, it is important to define the thermal comfort range 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 examining the effect of operative temperature on relative work performance (Lan *et al.*, 2012) 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 levels and time exposure of occupants in three different room conditions. The result is that the thermal comfort is the highest at 23°C, and that decreasing the temperature in winter and increasing it in summer for energy efficiency had a negative impact on occupants' performance. Two studies of Ornetzeder *et al.* (2016) and Tham and Willem (2010) proved that the preferred indoor air temperature for occupants' comfort is regardless of energy efficiency considerations.

Air quality. A workplace with good air quality has an impact on the health condition and satisfaction rate of occupants. Indoor air quality (IAQ) defines the air quality related to pollutants, contaminants, and ventilation. IAQ studies have found these issues by conducting a survey about irritation, headaches, fatigue and illness, which are related to sick building syndrome (SBS) symptoms (Seppänen *et al.*, 2006; Wargocki *et al.*, 2000). Stolwijk (1991) defined the SBS as "the occurrence of an excessive number of subjective complaints by the occupants of a building. These complaints include headache, irritation of the eyes, nose, and throat, lethargy, inability to concentrate, objectionable odours, and less frequently, nausea, dizziness, chest tightness, etc.".

Ventilation systems play a key role for air quality. Newsham *et al.* (2013) found that LEED-rated buildings provided higher satisfaction levels with the air quality than non-LEED-rated buildings. However, Ornetzeder *et al.* (2016) reported that occupants' satisfaction with the air quality was relatively low during winter due to dry air and low humidity. Schiavon and Altomonte (2014) stated that LEED buildings did not necessarily

affect occupants' satisfaction with the indoor environment. In line with earlier research, occupants in non-BREEAM certified offices tended to be more satisfied with the air quality than occupants in BREE certified offices (Altomonte, Saadouni, Kent and Schiavon, 2017). Particularly, modern office buildings that have an automatic air handling unit without openable windows could cause occupant dissatisfaction.

Noise control. Noise has a high relevance in office building design. The effect of noise can lead to distraction and interruptions in work processes of occupants. Noise in the office normally comes from colleagues, and it often occurs in the open-plan office (Ornetzeder *et al.*, 2016). Banbury and Berry (2005) stated that office noise would cause dissatisfaction with the work environment, and that the most disturbing noise source is a telephone left ringing. Altomonte, Schiavon, Kent and Brager (2017) revealed a strong relationship between noise, sound privacy and occupant satisfaction Noise performance not only has an impact on privacy but also productivity. For instance, open-plan offices have advantages in terms of good interaction and communication with colleagues (Heerwagen *et al.*, 2004). Kim and de Dear (2013) stated that enhanced interactions in open-plan offices do not compensate for distraction from noise. However, they found sound privacy a relatively unimportant factor in overall workspace satisfaction. The British Standards Institution recommends a range of background noise level that is acceptable for open-plan offices of 45–50 dB and for cellular offices of 35–40 dB (Field, 2008; Standard BS 8233, 2014). In European standards, the level for the cellular office is 30–40 dB and for the open-plan office 35–45 dB.

Light and daylight. Light conditions have an impact on visual comfort and are another factor with an influence on user satisfaction. Many studies have shown the correlation between daylight and user satisfaction. Groth (2007) found that lighting quality is important to attain user satisfaction. Kim and de Dear (2013) found that occupants in open-plan office were provided with more light than those in cellular offices. An *et al.* (2016) stated that more sun exposure was related to less depression and higher user satisfaction. The majority of office users prefer natural light over artificial light, for physical and psychological reasons (Galasiu and Veitch, 2006). Dissatisfaction with light quality was mainly caused by glare, and when the glazed percentage was under 40 per cent, people felt comfortable in their workplaces (Menzies and Wherrett, 2005). A research of Villa and Labayrade (2016) aiming for energy-efficient luminous environment identified an optimal solution to be suitable for different user requirements. In shared office spaces, the solution is to supply an individual task lamp that does not have a high-power demand (11 W each, LED lighting). Most problems of visual comfort were caused by too much sunlight (glare) coming from the south façade (Ornetzeder *et al.*, 2016). The window and shade system, in this point of view, are important factors for an outdoor view and to serve natural light. The preferred window size varies for different office conditions; a survey (Galasiu and Veitch, 2006) stated that the optimal window size on average needs to be in the range of 1.8–2.4 m in height to provide a wide lateral view.

3.3.4 Functional comfort factors. Functional factors are related to the suitability for work activities. When those factors have the right value, users can perform the work task efficiently.

User control. User control is considered as one of the important factors in relation to the cognitive aspect, since when the indoor environment is individually controlled, the user satisfaction is likely to increase (Proctor, 2014; Lee and Brand, 2005; Liu *et al.*, 2018; Loftness *et al.*, 2018). A research found that when office workers could control their own indoor environment, their health was improved (Raw *et al.*, 1990). Brager *et al.* (2004) revealed that occupants with a higher degree of personal control experienced most thermal satisfaction, and emphasised the importance of personal thermal control.

From an economic perspective, user control can cause a waste of energy due to inefficient thermal control (Shahzad *et al.*, 2016). In general, if people adjust to a cooler temperature during summer than the average temperature, and to a warmer temperature during winter, this will cause a greater energy use. According to Zhang *et al.* (2010), reducing the degree of personal control in workplace could save energy, but had no severe impact on user comfort. In addition, determining the optimal points of IEQ levels for various occupant types and the optimal operational strategy will be key to achieve both 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). Especially, the open-plan office has poor privacy conditions. On the other hand, combi and flex offices lead to higher satisfaction for privacy and concentration, since those offices still can provide back-up spaces (De Been and Beijer, 2014). However, the occurrence of privacy problems in an open-plan office depends on the density of workstations, office layout, people moving around, noise level, next to several other factors. High density might lead to decreased satisfaction due to the lack of privacy and unexpected social contact (Maher and von Hippel, 2005). On the contrary, a larger workstation with low density increases the satisfaction rate with acoustics and privacy (Leder *et al.*, 2016) because of a greater distance between colleagues. When privacy increased, the environmental satisfaction tended to increase (Duval *et al.*, 2002).

Concentration. Concentration implies being able to focus on work (Vos and van der Voordt, 2002). Studies dealing with concentration issues mainly compare the occupants experience between open-plan and cellular office, and investigate distracting factors. Concentration is disturbed by different elements: air quality, loud noise, and glare. In the work environment, concentration is a significant factor for a worker who has more single-oriented work task. Kaarlela-Tuomaala *et al.* (2009) revealed that the most distracting factor in open-plan offices was noise followed by too high or too low temperature. In private offices, temperature was the most distracting factor followed by draught, and noise was third.

Communication/collaboration. Improvement of the communication level is connected to productivity, and leads to effective collaboration (Heerwagen *et al.*, 2004), because better information exchange between colleagues and having more contact creates more understanding of each other (van der Voordt, 2003). Open-plan offices are believed to enhance communication and interactions between colleagues (Brand and Smith, 2005). On the contrary, open-plan offices have a potential sound disruption and lack of privacy (Kim and de Dear, 2013; Schiavon and Altomonte, 2014). One empirical study of De Been and Beijer (2014) explained that people were more satisfied with communication in combi offices than cellular and flex offices. Rothe, Beijer and van der Voordt (2011) proved that opportunity to concentrate and opportunity to communicate were the most important attributes, and privacy was found less important for productivity.

3.3.5 Psychological comfort factors. Psychological factors are related to spatial needs such as social and spatial comfort. These factors contribute to better work results and high level of satisfaction, although the absence of these factors does not mean that people are not able to work.

Social contact. Establishing social contact is another factor to satisfy user demands. The definition of social contact here means interacting with other people during break or to have a chat occasionally. This parameter is highly linked to office layout and workplace operation, but is not necessarily required for user satisfaction. Samani (2015) used the concept of social and spatial density defined by Duval *et al.* (2002). According to Samani (2015), increased density provided chances for building friendship, communication and environmental work satisfaction. Shier and Graham (2011) found that the overall well-being was affected by the relationship with colleagues.

Spatial comfort. Spatial comfort is another key factor that determines to which extent workers are satisfied and motivated in their workplace (Chandrasekar, 2011). Spatial comfort here defines that employees feel at home at their workplace. For example, they can insure their privacy, or they can have a sense of belonging in their working group through the spatial design of the office. Although this is a quite subjective factor, it is worthwhile to mention for office design: several studies have revealed that office workers who feel comfortable with their work environment tend to show better work results and have relatively higher 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 the office such as spatial configuration and density of workplaces. Kim *et al.* (2016) stated that flexi-desk users tended to be dissatisfied due to the issues about lack of territory and ability to personalise their work desks. Ikonne and Yacob (2014) found that spatial comfort significantly contributes to high level of satisfaction. A survey revealed that almost 90 per cent of the respondents found that better workplace layout and functional support result in higher overall workers' performance (El-Zeiny, 2012). Vischer (2008b) stated that a sense of territoriality and belonging is one of the typologies of the environmental psychology of workspace. Through other studies, it is identified that spatial comfort is only defined by workplace design and layout.

4. Discussion

This paper discussed the influential factors for user satisfaction and the importance of user satisfaction in office renovation processes. The definition of user satisfaction in this paper is different from job satisfaction of employees. Job satisfaction often includes emotional aspects of having a good working relationship with a boss or a leader or colleagues. Job satisfaction, however, is not part of the physical design approach in office renovations.

The physical and psychological factors that can increase user satisfaction were classified and analysed. The main challenge was how to compare the factors and evaluation of user satisfaction from different sources. Measuring human comfort and satisfaction is subjective, so the results might depend on the specific user's opinion. One possible method to deal with this is to employ a questionnaire. However, qualitative data gathered by empirical research would need to be further processed to reveal correlations between satisfaction and office design.

The theories of human comfort help to understand the priority of user needs and requirements, and to decide the extent of including user demands in office renovations to enhance user satisfaction. The categorisations of factors influencing user satisfaction that were introduced by other researchers are quite similar to each other. However, they also can be interpreted in various ways. This paper provides a classification which may help to examine user satisfaction based on the prioritisations of comfort.

5. Conclusions

This study reviewed factors affecting user satisfaction in work environments. Findings in this paper highlight ten influential factors (e.g. thermal comfort, air quality, lighting, noise, user control, privacy, concentration, communication, social contact and spatial comfort). In Figure 3, the ten factors are integrated into the three-step requirement structure: physical comfort, functional comfort and psychological comfort. Physical factors listed in the previous chapter do not only contribute to user satisfaction, but are also associated with energy use. Therefore, these ten factors should be included in a framework for achieving user satisfaction. Using this framework, designers or owners may decide to which extent they want to achieve user satisfaction and balance between energy saving and satisfaction.

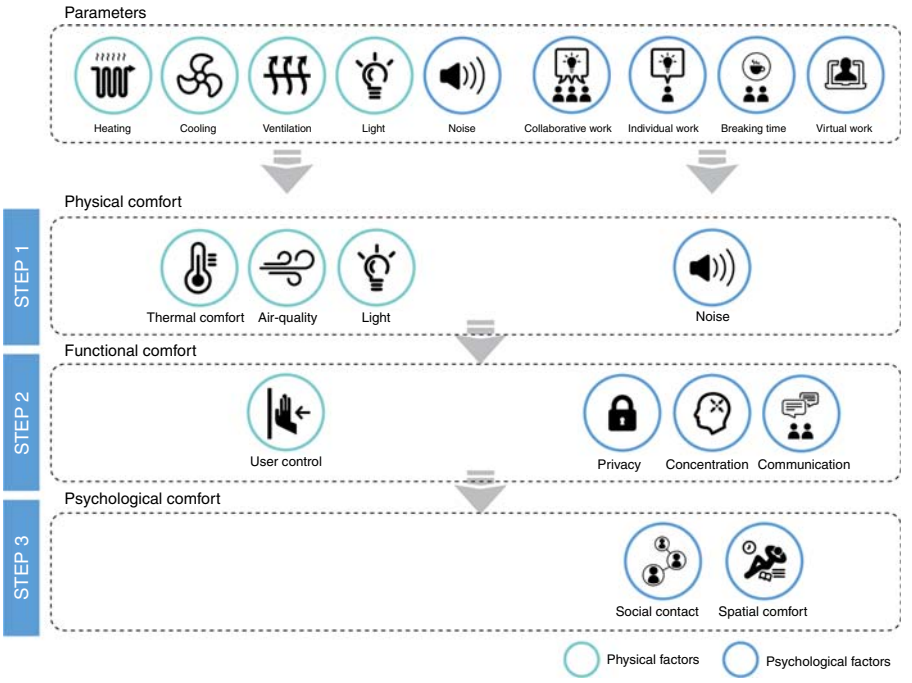

Figure 3.
Classification of physical and psychological factors based on the dimensions of comfort

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Further reading

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