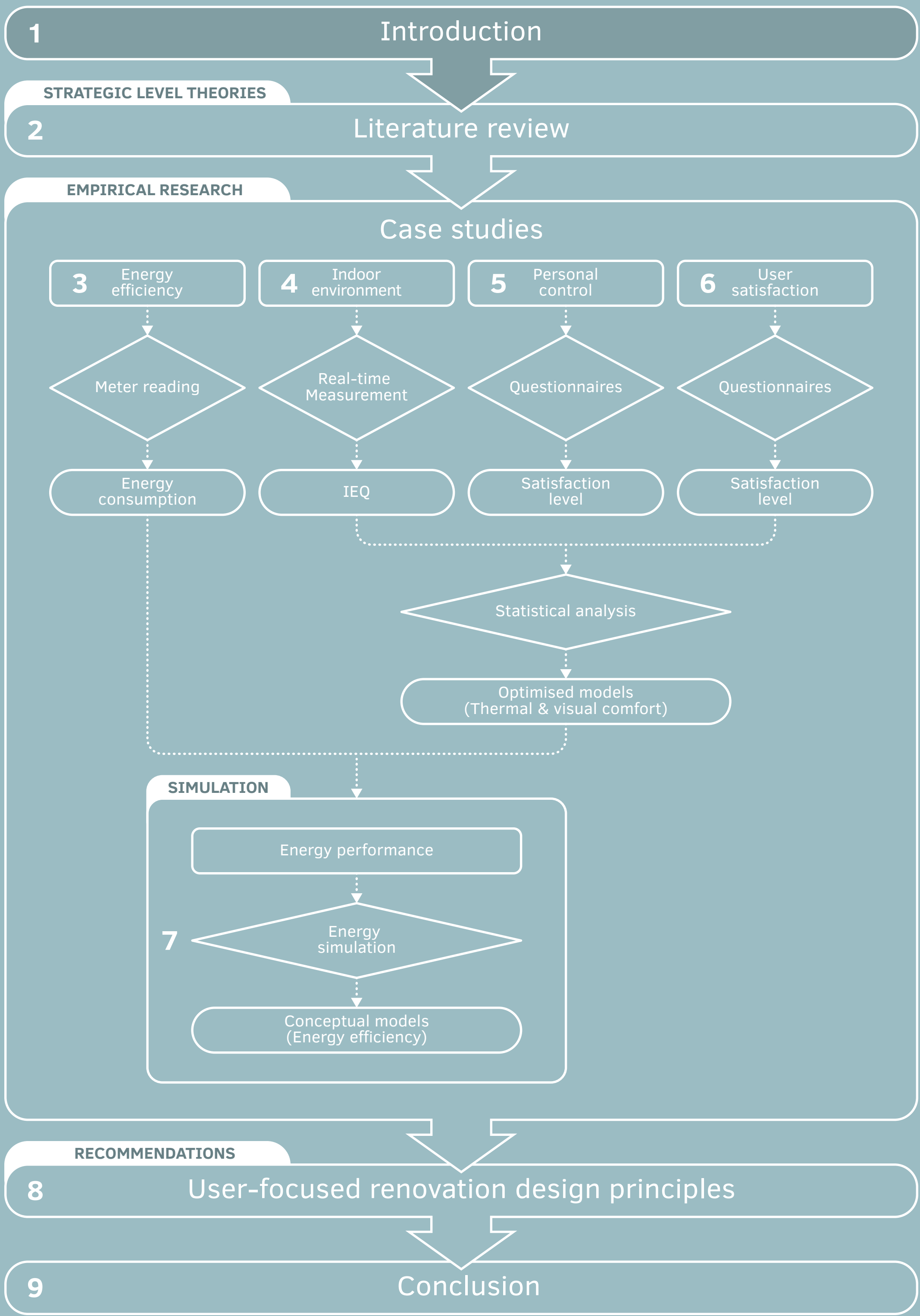
1 Introduction
STRATEGIC LEVEL THEORIES
2 Literature review
EMPIRICAL RESEARCH
Case studies
3 Energy efficiency
4 Indoor environment
5 Personal control
6 User satisfaction
Meter reading
Real-time Measurement
Questionnaires
Questionnaires
Energy consumption
IEQ
Satisfaction level
Satisfaction level
Statistical analysis
Optimised models (Thermal & visual comfort)
SIMULATION
Energy performance
7
Energy simulation
Conceptual models (Energy efficiency)
RECOMMENDATIONS
8 User-focused renovation design principles
9 Conclusion

TOC

1 Introduction

1.1 Background

The annual energy consumption of non-residential buildings in EU has increased during the last 20 years by 74%, which is 40% greater than in the domestic sector (Jung et al., 2018). FIG. 1.1 shows that the non-residential sector accounts for 18% of the total energy consumption, next to the residential sector with a 21% share. FIG. 1.2 shows that the office is the major energy using building type, with a share of 24% among non-residential buildings (CBECS, 2013). In other words, offices are responsible for the major part of energy consumption within non-residential buildings.

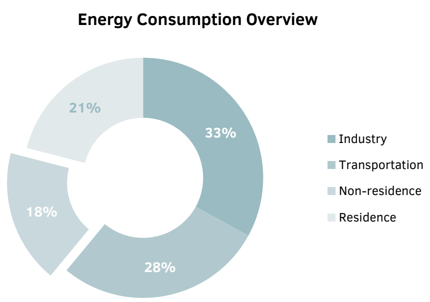

FIG. 1.1 Energy consumption overview (CBECS 2013)

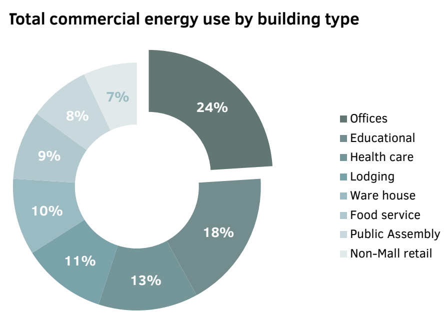

FIG. 1.2 Total energy use by non-domestic buildings (BPIE 2011)

In the European Union, around 85% of the 160 million buildings are showing thermally uneconomic conditions and bad energy performance (SwedishScienceNet, 2010). Consequently, global organisations and governments have paid attention to energy reduction through building renovations. The International Energy Agency (IEA), for example, reports that building renovation can contribute to a 50-70%

reduction in the overall energy demand of buildings (2016). Energy Performance Building Directives (EPBD) suggested several actions focusing on renovation and retrofitting to reduce existing buildings' energy needs (Mazzarella, 2015).

Energy-efficient building renovation in the built environment has received wide attention, particularly during the last decade. The EU has ambitious goals for energy reduction. According to the European commission and Energy Performance of Buildings Directive (EPBD, 2010; EuropeanCommission, 2016), compared to 2005, by 2050 the primary energy demand should be reduced by 32-41%. Many studies have stated that building renovations are important to achieve this goal (Bournas et al., 2016; BPIE, 2013; Kamenders et al., 2014; Marszal et al., 2011; Risholt et al., 2013). The building façade is one of the major considerations in building renovations. There are two reasons why facade technology is important for renovation. Firstly, the façade can significantly reduce the use of energy in the building. According to Mavromatidis et al. (2013), 50% of the total building energy is lost through the façade. This implies that improving the performance of the building envelope is important to save energy dissipated through facade. Secondly, the building envelope is an essential building element which can generate energy (e.g., applying photovoltaic technology).

Retrofitting is often defined as 'providing something with a component or feature not fitted during manufacture or adding something that it did not have when first constructed' (Eames et al., 2014). The European Parliament Directive (2002) reported that it is to modify the systems or the structure of something. Renovations are often used for the aesthetic improvement of buildings, but it also includes upgrades, repairs to certain elements of the building, removing, and adding new elements or systems for energy efficiency (Mazzarella, 2015). Thus, renovation covers a wide range of building upgrades.

From a sustainability perspective, maintaining an existing building can be preferable to demolishing an aging building and replacing it. However, it cannot solve the fundamental problems such as low quality of building components and mechanical systems since the building does not perform as it would be with new building requirements. Therefore, it is necessary to focus on renovating existing buildings in order to take a step forward for a sustainable built environment and to counteract the increasing operational costs of buildings. Hence, renovating existing buildings offers a great opportunity for cutting back energy consumption.

1.2 Problem statement

Energy-efficient office renovation is obviously required for the reasons mentioned in the previous section, and there is a great growth of energy renovation projects in practice. However, does a high energy performance office provide a comfortable working environment to its users? One of the reasons of office existence is to provide comfortable and healthy indoor environments (Ornetzeder et al., 2016). According to Klepeis et al. (2001), people spend over 80% of their time in enclosed spaces. Moreover, good indoor environments can lead to an increase of occupants' productivity (Al-Horr et al., 2016). For these reasons, planning healthy and comfortable work environment can be as important as reducing energy use. The question is, how can we design healthy and comfortable work environments, with which the users are satisfied? The starting point to answer this question is to include building users' requirements and satisfaction in workspaces in energy renovation schemes. A concern is that conventional renovation principles are mainly physical- and technical-oriented, whereas it does not focus on enhancing user satisfaction in the work environment. Moreover, as long as the renovated building does not offer sufficient quality or satisfaction, there will be less demand for renovated office buildings. When energy efficiency is considered as the only advantage of office renovation, it is difficult to convince developers, building owners, and investors that renovation is useful. From a managerial perspective, achieving better employee's satisfaction should be a focal point to strengthen the market values of renovated offices, thereby achieving a higher demand from the market, preventing environmental degradation or vacancy of existing buildings. Therefore, office renovation also has to provide a high-level of comfortable work environment for the users' well-being and satisfaction beside maximising energy reduction goals. Therefore, there is a significant need to investigate how to define the users' satisfaction to contribute to better office renovations.

The relationship between indoor climate and users' physical health has been explored in extensive research (Al Horr et al., 2016; Bluyssen et al., 2016; Leder et al., 2016; Mandin et al., 2017). Followed by these studies, the framework of international green building rating systems such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) include a category of social sustainability as a means of providing a healthy and comfortable environment to users for both new and renovated buildings (Sarkis et al., 2012; Zuo & Zhao, 2014). Although international green building rating systems address the significance of including user perspectives, there is a lack of guidelines and information that focus on user satisfaction in building renovation. Especially, the relationship between design factors and user satisfaction has rarely been investigated due to several reasons; user satisfaction is a subjective topic; design factors are closely related to energy efficiency and aesthetic aspects rather than user satisfaction. Therefore, the main problem is that in spite of the development of various renovation techniques, there is still a lack of renovation design principles considering user preferences and user satisfaction due to the indirect relationship with energy use.

In any renovation project, the initiative is the most significant phase to ensure proper decisions and to optimise overall renovation values and results, that should be considered in the early renovation design stage. Jensen and Maslesa (2015) stated that the main barriers include lack of standard principles and a lacking overview of potential values in the initiative phase. To summarise all these aspects, it is required to develop an overview of potential values and standard design principles that not only focus on energy efficiency but also on the building users for office renovations.

1.3 Research objectives and questions

1.3.1 Research objectives

The main objective of this research is to develop user-focused design principles for energy efficient office renovation that address the impact of office design factors on user satisfaction with thermal, visual, and psychological comfort through case studies in the Netherlands, and by evaluating user satisfaction in renovated office buildings.

1.3.2 Research questions

The main research question that will be answered is:

How can design principles for energy efficient office renovation be developed, based on the evaluation of user satisfaction?

In order to answer the main question, the following sub-questions need to be explored. Each question corresponds to a different chapter in the dissertation.

A What are the main parameters that are currently applied to evaluate user satisfaction in office buildings? (Chapter 2)
B How does energy performance differ between renovated offices and non-renovated offices on the basis of the façade renovation? (Chapter 3)
C What are the effects of indoor climate on physical and psychological satisfaction in the workspaces of the case studies? (Chapter 4)
D What is the impact of person control on user satisfaction with thermal and visual comfort? (Chapter 5)
E How do the office design factors affect user satisfaction with physical and psychological comfort? (Chapter6)
F To what extent do the office design factors contribute to the energy demand in different energy categories? Which combination of design variables constitute the optimal scenarios for energy-savings? (Chapter 7)
G How can user-focused design principles that optimise user satisfaction and energy performance be formulated? (Chapter 8)

1.4 Scope of research

The climate is very different worldwide. This research focused on case studies in the Netherlands, which is located in Cfb (Marine West Coast Climate) based on Köppen Climate Classification, to minimise complicated parameter requirements. However, the results suggest generic renovation principles that can be applied to any office model in similar climate zones.

A second consideration of this research is that offices have diverse characteristics according to different location, layout, size and materials. The renovation boundary in this thesis is restricted to the technical strategies for the building envelope and office functionality. Reasons for this are, first, that the building envelope has a major effect on improvement of the energy performance, and the mechanical service system, such as the heating, ventilation, and air conditioning (HVAC) system, is regarded as the most important renovation target. Second, the users' interest is only focused on the result of the building renovation instead of which technologies are used to improve the energy performance.

1.5 Research methodology

User-focused building evaluation is an important method to check the performance of a building in use (Heo et al., 2012). In order to examine the users' opinions, a mixed methods research design is applied to this research with three main study processes, which consist of literature review, real-time case studies including a user survey, and energy simulation. Before the start of the case studies, it is required to know the current state of the evaluation parameters for user satisfaction from literature reviews. Literature review contributes to sorting out the main parameters applied to user satisfaction evaluation in office buildings. The selected parameters are classified by the theoretical hierarchy of the user satisfaction framework in office design.

1.5.1 Research approach

FIG. 1.3 shows four stages of user-focused evaluation of offices that are conducted in this research. A quantitative and qualitative research approaches are chosen to convert observation in real-time contexts into generalisable principles. First phase focuses on collecting data from the field study consisting of three parts. The quantitative research includes two observation methods: real-time monitoring of the indoor climate and distributing questionnaires to users. In phase 2, statistical and comparative analyses are conducted to verify the reliability of the collected data. In phase 3, the collected data are used as input to formulate generalised design principles. In phase 4, energy simulation by design builder software is applied to assess the generalised principles and to validate adequacy for energy efficient renovation.

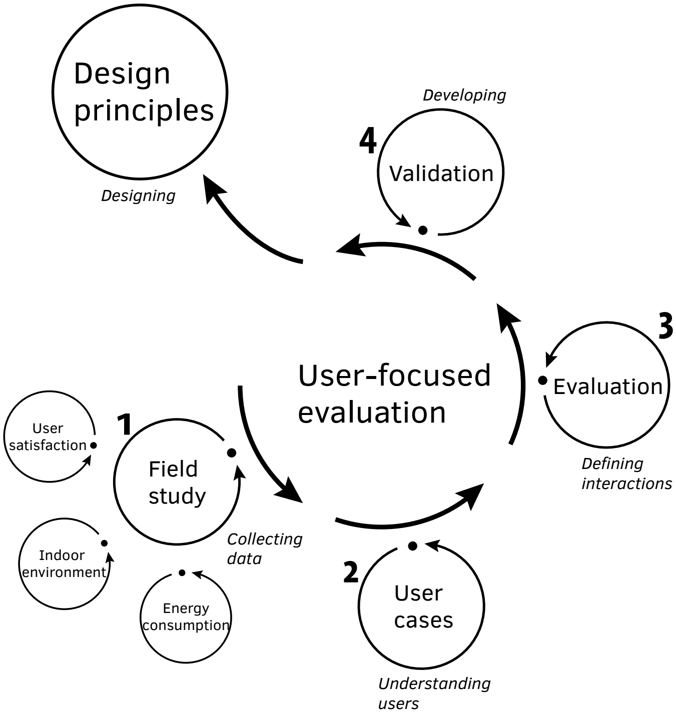

FIG. 1.3 User-focused evaluation research approach

1.5.2 Research methods

This research applies three data collection methods regarding the three main research topics (energy, indoor environment, and user satisfaction). In addition, the two analyses methods are conducted to validate the results (statistics and energy simulation).

A Literature study

Literature reviews are used to investigate the most important factors for user satisfaction on workplaces, and exploring the gap between real workplace and theories from the findings of former studies. The theoretical framework contributes to create the hierarchy of satisfaction factors.

B Case study

B1 Interviews

Facility managers and architects are invited to collect the building information. In addition, the information of the annual energy consumption of case studies is collected by meter-reading.

B2 Measurement of indoor climate

Real-time monitoring of indoor climate was conducted with HOBO devices, which can measure indoor air temperature, relative humidity, and illuminance, in five case studies in the Netherlands.

B3 User survey

Questionnaires are distributed to the building users to collect the degree of user satisfaction with, and perception of workplaces.

C Energy simulation

Energy simulation is conducted by using the software Design Builder. The results assume the energy demand based on the different combination of office design factors.

1.6 Research framework and outline of the thesis

This thesis presents empirical and simulation-based results. A research framework is developed to answer the research questions. It consists of eight chapters, as shown in FIG. 1.4. This research is approached by focusing on three aspects: energy efficiency, indoor environmental quality (IEQ), and user satisfaction.

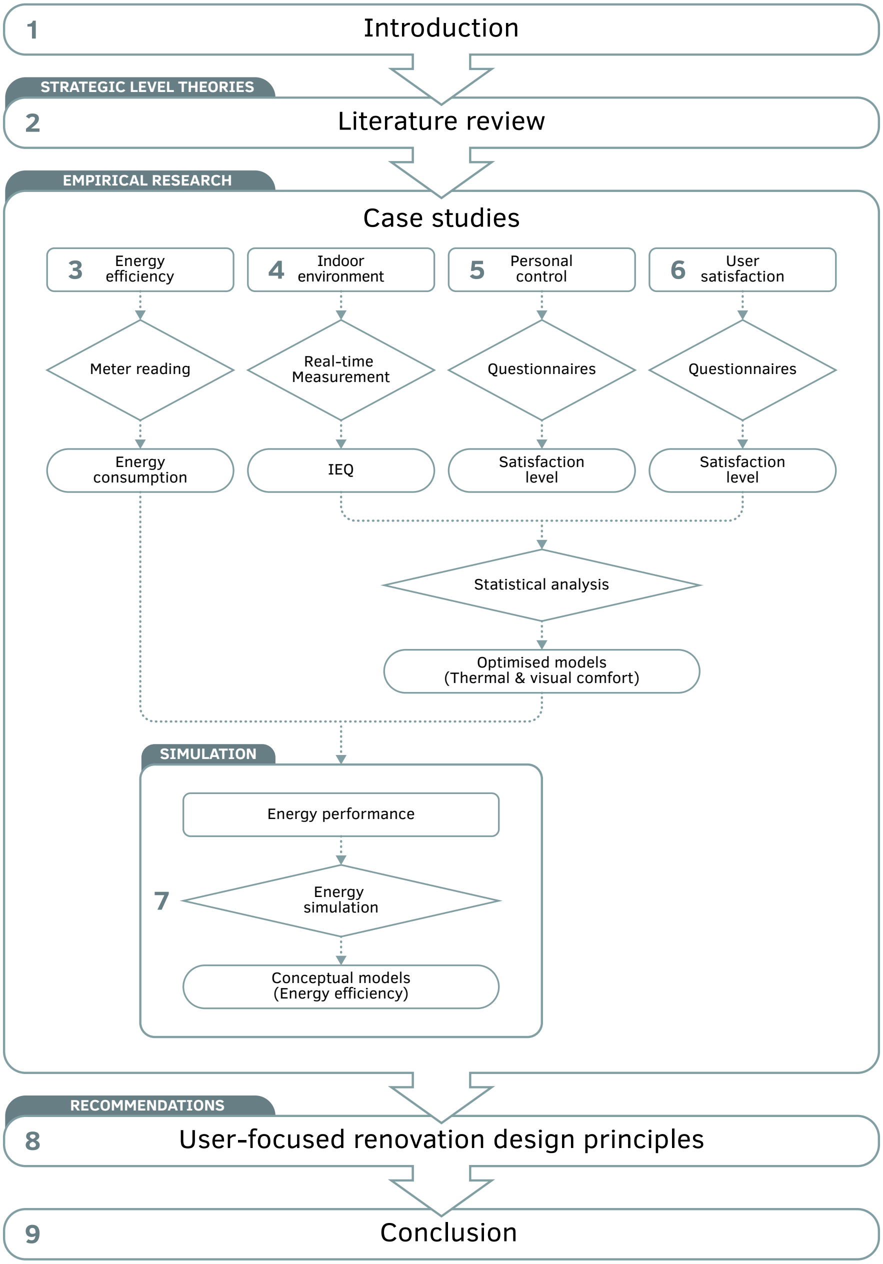

FIG. 1.4 Research structures and methods

Chapter 2 provides the main parameters currently applied for the evaluation of user satisfaction, including the definitions based on literature reviews. Ten key indicators for users' satisfaction in workspaces are discussed and structured based on the priority of users' needs.

In order to identify the impact of building characteristic of renovated offices on energy performance, Chapter 3 compares the performance of renovated and non-renovated offices in terms of energy efficiency and the characteristics of renovated office buildings.

The results of empirical studies conducted in the Netherlands is presented in Chapter 4. It compares the effect of indoor climate on user satisfaction in each case study, and investigates the seasonal adaptive thermal comfort and users' thermal perception.

Chapter 5 explores the relationship between the office design factors and user satisfaction with physical and psychological comfort. Multi-statistical analyses were conducted to investigate influential office design factors on user and its contribution weight on satisfaction. The findings show predicted satisfaction models and which design factors may bring better satisfaction to users.

The predicted models in Chapter 5 are simulating the energy performance to verify energy consumption in Chapter 6. This chapter assesses the impact of design factors on energy performance using possible combination models and energy efficiency and presents optimal energy reduction models.

The integrated design principles were formulated based on the findings of the previous chapters. Chapter 7 describes the optimal models based on both energy efficiency and user satisfaction. Furthermore, the optimal model proposes optimised user satisfaction and energy performance.

Chapter 8 concludes the user-focused design principles with recommendations, and practical implications to improve the quality of work environment in the future.

1.7 Research relevance

1.7.1 Scientific relevance

This aims to bridge the gap between energy efficient renovation principles and realised office conditions by reflecting on non-technical considerations such as users' thermal, visual and psychological satisfaction in a scientific way. Understanding users' satisfaction and requirements is a fundamental research step to develop a user-focused office renovation.

This research is, therefore, highly related to the topic of indoor comfort and user satisfaction with thermal and visual comfort. On the one hand, most of scientific studies among the topics deal with the influence of design parameters on a certain satisfaction parameter such as visual or thermal comfort. On the other hand, the user-centred approach focuses on human behaviour and its pattern in a workspace. However, the condition of the workspace is created by many design factors. Moreover, the interplay among different design factors can influence differently on user satisfaction. Therefore, this research considers the different design factors as a whole and its importance on user satisfaction.

The user-focused design principles in this research provide estimated satisfaction values for possible combinations of design factors. The design principles for office renovation suggest how the principles can be applied in practice and shows the contribution weight of the design factors on different types of user satisfaction. The predicted satisfaction models were tested by simulating their energy performance. The models can contribute to an estimate of the energy demand of each typology and the level of satisfaction.

In addition, the mixed-methods applied in chapter 4 can contribute to the user-related studies for building evaluation. The recommended design principles can contribute to energy efficiency and user satisfaction as a result. It is expected that the results of this research will be a starting point for considering new work environment and user-focused choices. Furthermore, it will contribute to applying user consideration into any energy-efficient office renovations.

1.7.2 Social relevance

This research investigates the impact of design factors on user satisfaction and introduces user-focused design principles for office renovation. Energy-efficient office renovation with a consideration of building users is often a challenging task to developers and other professionals since the satisfaction is subjective and difficult to measure. For this reason, renovation was not often supported by users' perspectives. In this research, office design factors are analysed from new perspectives focusing on the user perspective. The results are expected to have an impact on sustainable office design and better work environment, thereby increasing employees' satisfaction and productivity, and reducing the rate of absenteeism. When an energy renovated office serves as a favourable work space, the market demand for this type of office can be expected to increase. Therefore, besides better physical indoor quality and energy savings, this research will contribute to better workspace quality considering thermal, visual and psychological satisfaction for users. Furthermore, user-focused energy efficient renovation will open a new chapter for an advanced-sustainable built environment in society and will guide architects, facility managers, and owners towards extra advantages; higher productivity, higher market value, and so on.

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