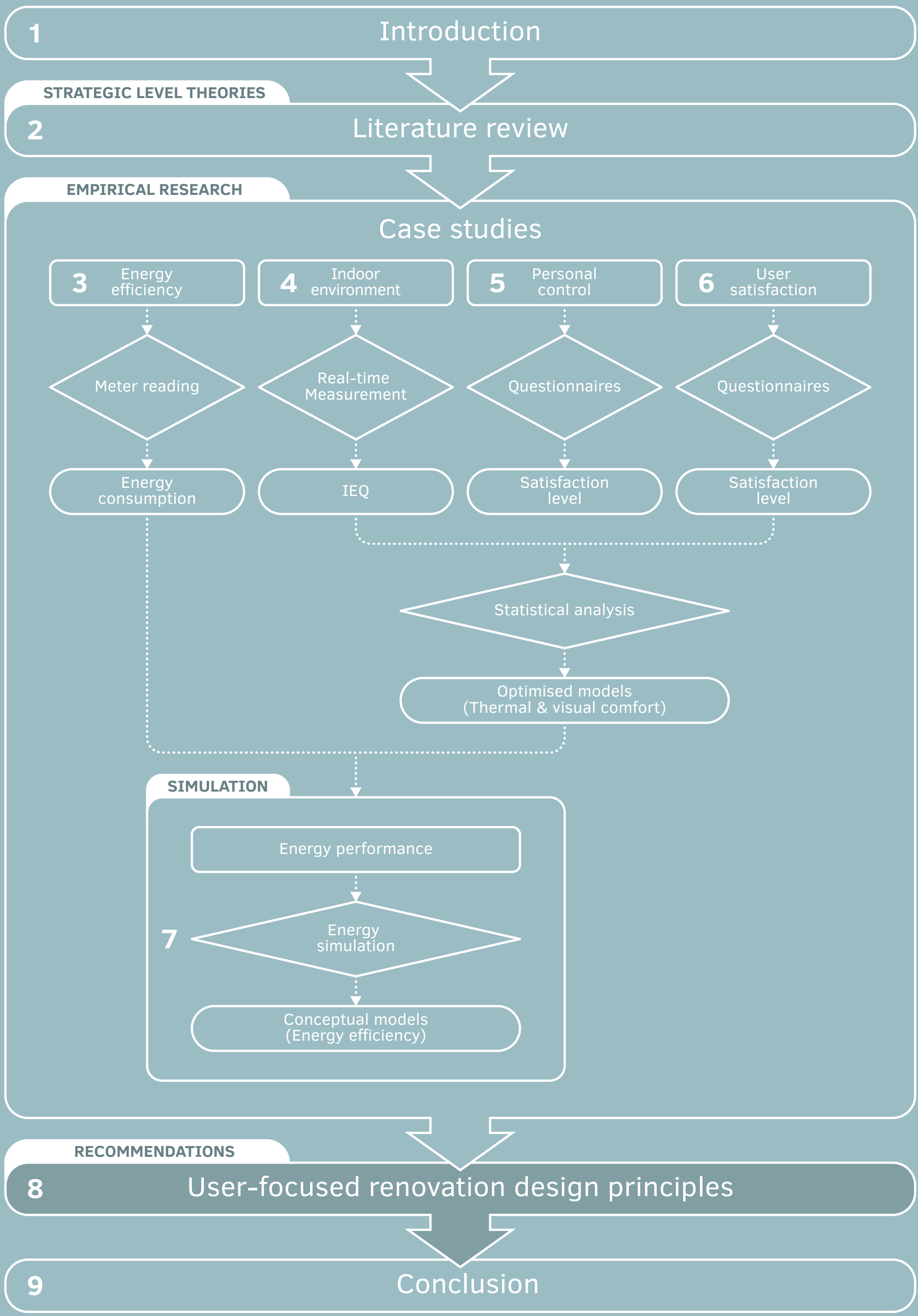
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8 User-focused design principles

Chapter 7 tested the energy demand of possible office typologies. However, the main aim of the thesis is to develop user-focused design principles for energy efficient office renovation. Therefore, it is important to compare the degree of user satisfaction of highly energy-efficient office typologies. Based on the results from chapter 7, chapter 8 introduces design principles that architects, and facility and real estate managers can use to select the combination of parameters with better user satisfaction during a conceptual design stage of office renovation. It contains a database of the different degrees of user satisfaction with thermal, visual, and psychological comfort, according to the combination of design parameters.

Section 8.2 explains the design principles considering user satisfaction and energy efficiency. Section 8.3 provides the overview of predicted satisfaction of 144 office combinations. Recommended office combinations based on energy efficiency are explained in section 8.4. Section 8.5 describes the process of application of the design principles: how can designers interpret and use the principles and predicted models for energy-efficient office renovation?

8.1 Introduction

The goal of user-focused design principles is to increase user satisfaction and comfort, which can lead to the increase of productivity in energy-efficient office renovations. The integration of office design factors with user satisfaction is relatively new. Assessing the building users' actual satisfaction enables the investigation of the relative impact of office design factors. This chapter explains the overview of the outcomes from the previous chapters. The principles focus on five points, such as the users' thermal, visual, and psychological satisfaction, the reduction of energy demand, and the degree of personal control. Next, an overview of predicted user satisfaction models is given, based on the findings regarding user satisfaction from previous chapters. The new design principles for renovation and the graph giving an overview of predicted satisfaction, created in this research project, can support architects, facility and real estate managers in their decisions.

8.2 Design principles for energy-efficient office renovation

This section proposes predicted models for office renovation based on user satisfaction and energy efficiency. In order to make user-focused design principles applicable in practice, the models were simulated in terms of energy efficiency. The principles were built upon user experience rather than building performance. The comprehensive outcome provides a common ground for user-focused energy efficient office renovation by combining different perspectives of satisfaction. Multiple perspectives of satisfaction were considered to predict satisfaction in workspaces. The design factors included in the predicted satisfaction models included: orientation, window-to-wall ratio (WWR), layout, and desk location distance from a window, and thermal, visual, and psychological comfort as satisfaction variables.

FIG. 8.1 illustrates the design principles based on user satisfaction and energy efficiency. During the renovation process, architects, facility and real estate managers need to decide which perspective of user satisfaction is prioritised.

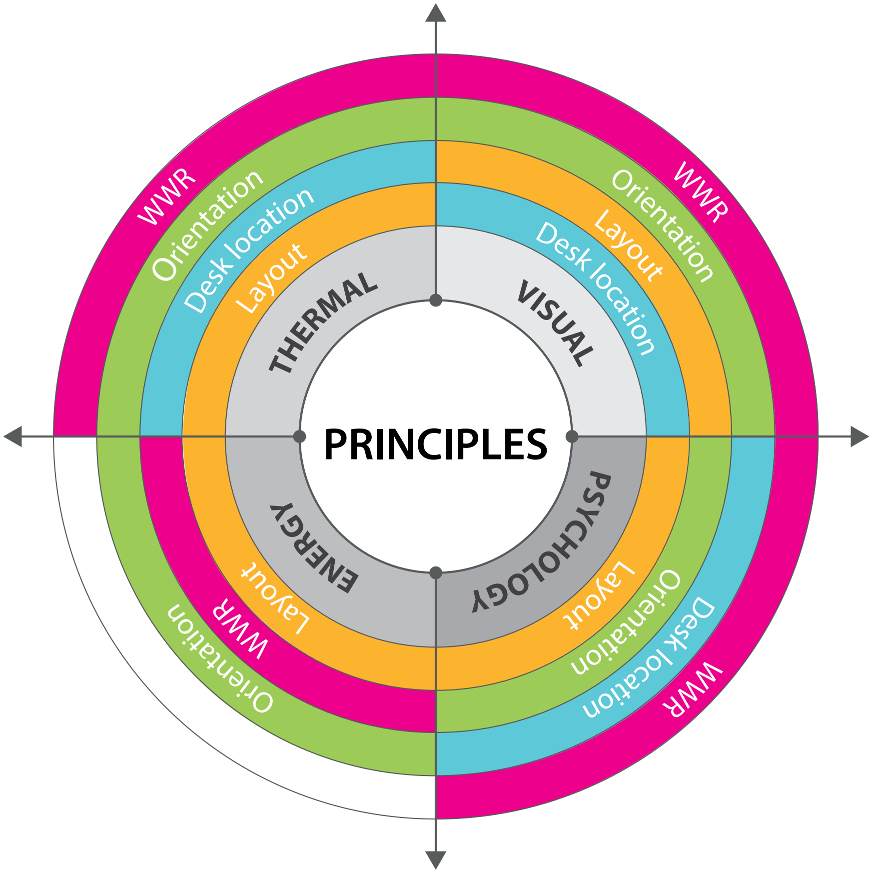

FIG. 8.1 User-focused design principles for energy-efficient offices (Radial axes moving outwards from the centre mean decreasing importance)

Five design principles for energy efficient office renovation were built based on FIG. 8.1 considering design factors and energy efficiency.

Principle 1: Focus on user satisfaction with thermal comfort

To increase user satisfaction with thermal comfort, the floor layout should be considered as first priority since it is the most influential factor for the users' thermal satisfaction, followed by desk location, orientation, and WWR (see FIG. 6.4). In contrast, the WWR has the smallest impact on thermal satisfaction. Firstly, cellular and flexible office layouts can be recommended to improve thermal satisfaction, followed by the combi office. Secondly, desks located over 4 metres away from windows can provide better thermal conditions. In addition, there is no significant difference between desk locations 0 – 2 metres away and 2 – 4 metres away from windows, showing considerably lower thermal satisfaction. Finally, workspaces orientated north-west provide the optimal condition for thermal satisfaction.

Principle 2: Focus on user satisfaction with visual comfort

Organising the optimal desk location can contribute to the user's visual comfort. Similar to the recommendation for thermal satisfaction, desk locations far away from windows are better for overall visual comfort than close to windows. Following common sense, people prefer to sit next to windows. However, the findings in this research show the opposite results. The reason why is assumed to be that visual comfort indicates not only outside view but also lighting quality, and light and glare might be too bright next to the windows. Therefore, to sit far away from a window may improve the overall visual comfort. Layout is the second most important contributor to visual satisfaction. The flex office is recommended as first option, followed by the combi or cellular office. There is no big difference in the level of visual satisfaction between cellular and combi offices. A north-west orientation is found to be optimal, followed by south-east. Visual satisfaction can fluctuate through different seasons in the north-east orientation. The WWR is considerably more important for intermediate seasons but not for summer or winter. A larger WWR tends to bring higher visual satisfaction.

Principle 3: Focus on user satisfaction with psychological comfort

Chapter 2.2 explained the user satisfaction variables based on literature. Psychological comfort here considers five variables: privacy, concentration, communication, social contact, and territoriality. Layout and orientation are the main factors that contribute to psychological satisfaction. However, layout is not a statistically significant factor for social contact. Although desk location does not highly contribute to the user's psychological satisfaction, the factor needs to be considered mainly for social contact. Cellular and combi office types can be applied when high privacy and concentration are required. On the other hand, open and flex offices are not recommended for privacy and concentration. The orientation brings very diverse results according to psychological variables; therefore, there is no definite suggestion. Similar to the recommendation for thermal comfort, desks located over 4 metres away from a window are optimal for satisfaction while putting them 2 – 4 metres away from a window is not recommended for the function of full-day working spaces. Furthermore, either more than 80% or less than 30% WWR can bring better concentration to the occupants (FIG. 6.5).

Principle 4: Focus on energy efficiency

As FIG. 7.5 shows in chapter 7, office layout and WWR are the main design factors when considering energy savings. A larger WWR leads to more energy use in a workspace. The cellular office is the most energy-efficient layout, followed by the flex office. The combi office can also be applicable in practice. However, the office layout should only be designed with a WWR smaller than 50%, otherwise the energy efficiency will drastically drop. The open plan office is the least energy-efficient layout among the four types studied. Even though an open plan office combined with the smallest WWR can be a positive option, this type still can consume a considerably large amount of total energy, similar to the combi office designed with a WWR greater than 80%. The orientation is not a critical factor for the total energy use of an office building since office buildings often have two opposite sides of glazed or opaque façades. In addition, the orientation is already decided in renovation.

Principle 5: Focus on the degree of personal control

Personal control is directly and indirectly related to user satisfaction. This research revealed that the users' thermal and visual satisfaction can be increased by providing more personal control of the work environment. At the same time, personal control is highly connected to psychological impact. A façade-related factor such as the WWR is important in terms of the energy consumption of a building, while it is relatively less important for user satisfaction. Nevertheless, the façade-related factor cannot be excluded in user studies. Chapter 5 concludes that façade-related aspects can be explained by personal controllability.

The degree of personal control is defined in chapter 5 as follows:

- Complete control: no central control system and full control by users, and they have wide range of temperature control.
- Partial control: having set-points, occupants are allowed to control their own environment within the limited thermal range.
- No control: fully centrally controlled conditions, the control system is installed, but people are not allowed to use it.
- Do not have: no user control system is installed.

The summary of the relationship between personal control and thermal and visual satisfaction is listed below, mentioning the most important factor first and the least last.

Thermal comfort

- In intermediate seasons for heating and ventilation (openable windows): ‘complete’ > ‘partial’ > ‘do not have’ > ‘no control’,
- In intermediate seasons, for cooling: Do not have > complete > partial > no control,
- In summer, for cooling: ‘complete’ > ‘partial’ > ‘do not have’ > ‘no control’,
- In summer, for ventilation: ‘do not have’ > ‘complete’ > ‘partial’ > ‘no control’,
- In winter, for heating: ‘complete’ > ‘partial’ > ‘do not have’ > ‘no control’,
- In winter, for ventilation: ‘do not have’ > ‘complete’ > ‘partial’ > ‘no control’

Visual comfort

- Occupants can easily accept that they do not have personal control than that they cannot use the available control system.
- Sunshades: the degree of control of ‘complete’ > ‘partial’ > ‘do not have’ > ‘no control’ is suggested in intermediate seasons and summer.
- Sunshades: in winter, ‘complete’ > ‘partial’ > ‘no control’ > ‘do not have’ can be recommended for lighting, and ‘partial’ > ‘complete’ > ‘no control’ > ‘do not have’ for the aspect of view to the outside.
- Artificial lighting: the degree of control of ‘complete’ > ‘partial’ > ‘no control’ > ‘do not have’ is suggested for the intermediate seasons and winter.
- Artificial lighting: in summer, ‘partial’ > ‘complete’ > ‘no control’ > ‘do not have’ is suggested for the design of the degree of personal control.

These results show that complete control is not always the best solution for visual comfort. In summer, the predicted visual comfort according to the degree of personal control is different from other seasons.

8.3 Overview of predicted satisfaction models

The design principles illustrated in the previous section have varying degrees of importance for user satisfaction in energy-efficient office renovations. However, all design factors influence each other in the actual work environment which leads to a multiplicity of satisfaction models. 144 are visualised graphically to show the overview of predicted satisfaction values, based on the combination of design variables in FIG. 8.2. By means of this figure, designers can predict the degree of user satisfaction regarding thermal, visual, and psychological comfort, according to the combination of different design factors. As chapter 2 has shown, the occupant's physical comfort, such as thermal and visual comfort, should be considered as first priority since they are highly related to health and productivity. When thermal and visual conditions, as basic requirements for a workspace, are not met, occupants will not perform efficiently, and severe dissatisfaction may occur.

Coloured dots and lines indicate the mean value and quartile of predicted satisfaction with thermal, visual, and psychological comfort. The numbers mean: 2 = dissatisfied, 3 = neutral, and 4 = satisfied. The scale 1 and 5 are excluded since there is no case around the scale. A higher number means greater satisfaction. Orientation is placed in the centre of this graph because the orientation is an unchangeable condition in building renovation. Recommended design options are highlighted in this graph. There are several options, using different design principles, for each layout to increase satisfaction. However, due to the lack of cases for the combi office, finding an option that satisfies the users is difficult.

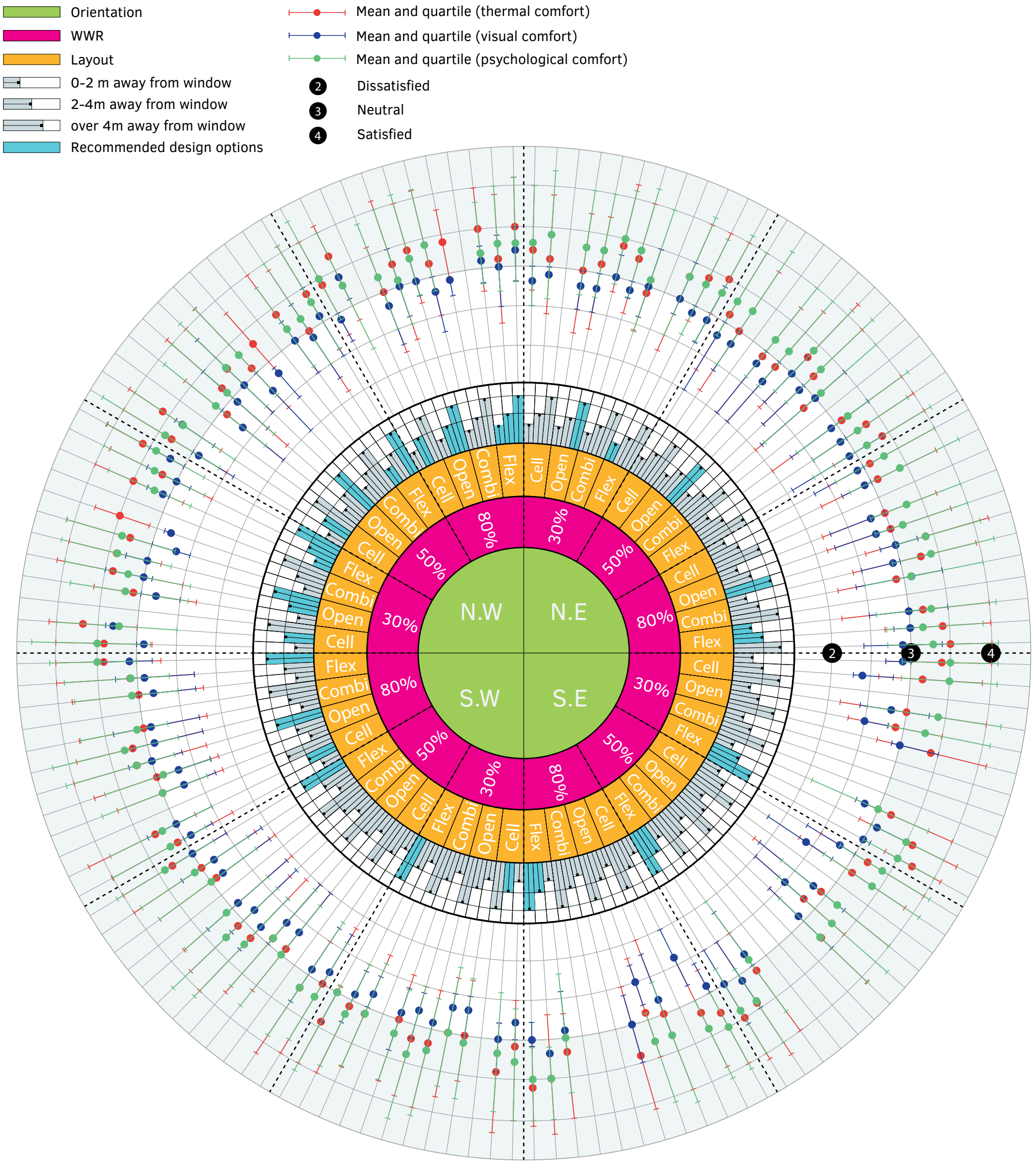

FIG. 8.2 Overview of predicted user satisfaction according to the combination of office design factors

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8.4 Overview of energy-efficient office types

TABLE 8.1 shows the overview of energy-efficient office types that can improve both satisfaction and energy efficiency. This overview helps to identify the possible office typologies depending on the aim of the renovation projects. On average, office buildings with glazed façades facing north-west/south-east are recommended to create better work environments for occupants than the ones facing north-east/ south-west. In terms of user satisfaction, the flex office can be highly recommended to increase the users' thermal, visual, and psychological satisfaction, regardless of desk location or WWR for north-west oriented workspaces. For energy efficiency, cellular and flex-offices are the most energy-efficient types, regardless of the orientation, and a WWR not greater than 80% should be designed for office renovations. The design options suggested for energy efficiency can achieve 23% to 28% of total energy savings compared to open plan office types with a larger WWR. Furthermore, the percentage of energy savings are not significantly different among the suggested design options. Therefore, the design alternatives are not strictly limited to several office types.

TABLE 8.1 Overview of energy-efficient office types

Energy	Orientation	WWR	Layout	Percentage of saving
	N.W/S.E	30	Cellular	6.3%
	N.E/S.W	30	Cellular	6.3%
	N.E/S.W	30	Flex	3.4%
	N.E/S.W	50	Flex	3.1%
	N.W/S.E	50	Flex	2.9%
	N.W/S.E	30	Flex	2.9%
	N.W/S.E	50	Cellular	2.7%
	N.E/S.W	50	Cellular	2.7%
	N.E/S.W	30	Combi	1.8%
	N.W/S.E	30	Combi	1.1%
	N.W/S.E	50	Combi	0.1%
	N.E/S.W	50	Combi	Standard

8.5 Application

This section explains how the principles and the overview graph can be applied during a renovation process. This applies to Cfb climate zone. Other climates or the Southern Hemisphere would require additional research. FIG. 8.3 shows the application process. Following the application process leads to the suggested renovation solutions to optimise satisfaction. The first step is finding the current physical office condition of existing buildings in the predicted satisfaction model, and second checking the satisfaction value (see FIG. 8.2). The third step is checking which satisfaction categories need to be improved. If the existing type is one of the recommended cases it is still advisable to check which factors can still be improved. After that, the application process proposes to go back to FIG. 8.1 and follow the order of important design factors to improve satisfaction with thermal, visual, and/or psychological comfort.

In reality, because of the conditions of the specific office, the possibilities to renovate in a certain direction are limited. For example, sitting far away from a window is illogical in the cellular office, due to the spatial efficiency and the size of a room. Therefore, it could be difficult to apply the renovation options recommended. In this case, the aspect of building services (designing the degree of personal control) can be a way to enhance user satisfaction through office designs. When it is possible to find the optimal design combination to improve user satisfaction, the energy performance of the option can be determined. Finally, the recommended degree of personal control can be applied.

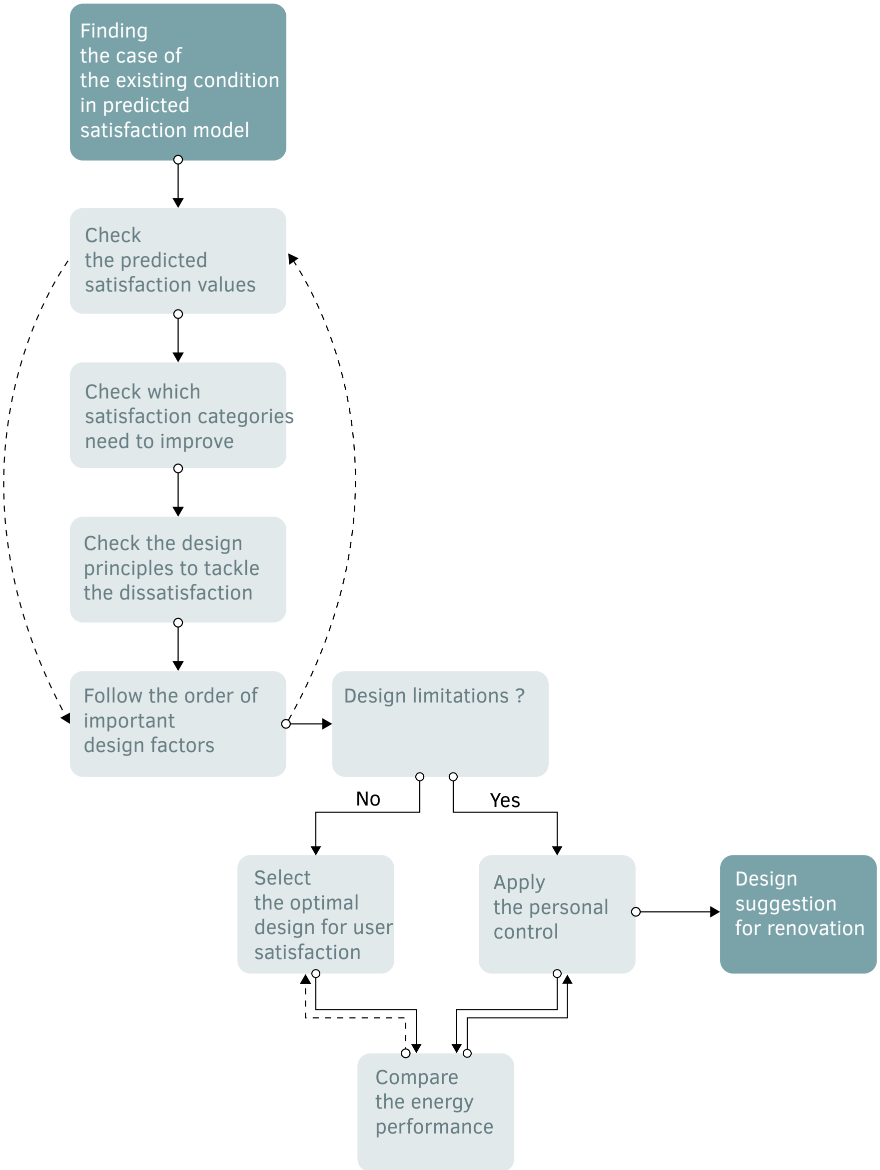

FIG. 8.3 Application of design principles in renovation process

8.6 Conclusion

The aim of this chapter is to elaborate how can the user-focused design principles be applied by architects, facility and real estate managers to energy-efficient office renovations during the design process, and how should they follow the principles and the predicted satisfaction overview model. To achieve this aim, the degree of importance of design factors for user satisfaction and energy efficiency was illustrated through the multidisciplinary analyses, and the application process is developed to guide people who will use the principles. Architects, facility and real estate managers should check the actual conditions of the existing office building, then explore the optimal combination of design factors with the predicted satisfaction value. What needs to be highlighted in this research is that the open plan office layout is a common type in office buildings, because the openness of the workspaces increases communication between employees, and is more space efficient, thereby cost efficient. However, in this research, the open plan office is not only a type that requires more energy, but also causes user dissatisfaction. For this reason, designing an open-plan office requires more attention and research to tackle these problems. Furthermore, there is not one answer to satisfy both energy efficiency and user satisfaction. In practice, these suggestions may be compromised by aesthetic issues or other factors, and technical building conditions can affect these design options as well. Therefore, it is important to make a balance between design considerations, energy performance and user satisfaction, and finding the optimal design solution instead of giving weight to only one aspect.