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Energy and comfort in contemporary open plan and traditional personal offices

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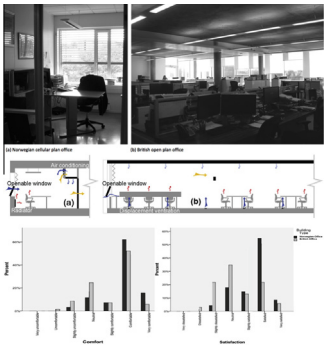
HIGHLIGHTS

- User satisfaction is compared in offices with high and low thermal control.
- Thermal control is secondary in British and main system in Norwegian approach.
- Individual thermal control in Norway improved satisfaction (35%) and comfort (20%).
- The energy use is much higher in the Norwegian than British case studies.
- A balance is required between energy efficiency and providing thermal comfort.

GRAPHICAL ABSTRACT



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ABSTRACT

Two office layouts with high and low levels of thermal control were compared, respectively traditional cellular and contemporary open plan offices. The traditional Norwegian practice provided every user with control over a window, blinds, door, and the ability to adjust heating and cooling. Occupants were expected to control their thermal environment to find their own comfort, while air conditioning was operating in the background to ensure the indoor air quality. In contrast, in the British open plan office, limited thermal control was provided through openable windows and blinds only for occupants seated around the perimeter of the building. Centrally operated displacement ventilation was the main thermal control system. Users' perception of thermal environment was recorded through survey questionnaires, empirical building performance through environmental measurements and thermal control through semi-structured interviews. The Norwegian office had 35% higher user satisfaction and 20% higher user comfort compared to the British open plan office. However, the energy consumption in the British practice was within the benchmark and much lower than the Norwegian office. Overall, a balance between thermal comfort and energy efficiency is required, as either extreme poses difficulties for the other.

1. Introduction

Most buildings are either comfortable or energy efficient [1] and human comfort is often overlooked in buildings using high sustainable strategies. 40–50% of energy in buildings is used for thermal performance purposes, including heating, cooling and ventilation [2]. Recent studies indicate that high efficient air conditioning systems can significantly reduce the energy and carbon dioxide emissions [3–5]. There is a lack of knowledge in comparing the traditional personal and contemporary open plan offices in regard to human comfort and energy use. Furthermore, the advantages of the traditional personal offices are overlooked. Individual

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control over the thermal environment is a significant difference between these two office typologies. The application of thermal control in the workplace is reported to improve user comfort [6–10] and to reduce energy consumption [11–15]. However, managing a balance between energy and comfort is challenging [16]. Recently, control, comfort and energy have become the focus of many studies [17–23].

The history of the workplace shows users' demand to control their thermal environment [24]. Nevertheless, the twenty-first century climate and economic challenges as well as organisational changes and new ways of working drive the office design further away from user control. The best practice examples of traditional offices with high levels of control are designed in Scandinavia. However, these offices are being replaced by open plan offices [25,26] and user control by centrally operated thermal systems [9,27]. There is a contradiction in predicting the necessity of providing user control over the thermal environment in the future, as Leaman and Bordass recognised it as an essential asset [28], while Harris claimed that it is unnecessary, due to flexible ways of working and unnecessary application of assigned workstations [29]. Concerns regarding the lack of knowledge of thermal control are reported [10]. This work compares the energy consumption and users' view of individual thermal control over the thermal environment in two offices that provide high and low levels of thermal control, the traditional Norwegian cellular and the British open plan offices, respectively.

2. Previous related work

Rollins and Swift emphasise the significance of occupant views regarding the notion of control, as 'to be in control and not to be at the mercy of external forces' [30]. The comfort literature recommended the application of thermal control [31], which is associated with improving user comfort [5–10] and satisfaction [5–9,32–34] in the workplace. However the research in this field mainly focuses on the open plan offices. It is established that adaptive opportunity or thermal control is based on the flexibility of the building to provide control for occupants to adjust the thermal environment [35–37]. Furthermore, an environment with high adaptive opportunity is likely to prove more comfortable than one with low opportunity, because people will take advantage of the actual and potential variations in room temperature [35,36]. Access to thermal control, such as a thermostat, improves user satisfaction [38,39]. Leaman determined that perceptions of good control are often associated with better comfort and satisfaction and environmental control systems, which are responsive, accessible, simple and user friendly, increase user satisfaction [8,37]. Acceptance of the thermal environment is directly related to the expectation of the occupant, and there are individual differences in perceiving this environment and users' expectation of comfort as well as a controlled and refined thermal environment is increasing [40,41]. Bordass et al. established that although building managers prefer to eliminate user control of the thermal system, lack of local control is associated with more discomfort, and more management time is required to respond to complaints [9]. Thermal and environmental control are recommended as part of the architectural design of the building and visual access to outdoor climatic conditions is suggested [35]. However, environmental control is considered mainly for 'fine-tuning' in case of a system failure [11] rather than the main system to control the thermal environment.

This study examined human comfort and energy consumption when high and low levels of control over the thermal environment were provided for occupants in traditional personal and contemporary open plan offices, respectively. It examined the impact of different factors, including temperature, humidity, air velocity, indoor air quality, and lighting, as well as user users' preference to adjust them on human comfort and satisfaction. For this reason, two distinct workplace contexts based on different architectural designs and contexts of the two countries were used as case studies. The context of the two countries [42] and the impact of Works' Council and work regulations influenced their design of the workplace and environmental control [24]. After the Second World War, Scandinavian and Anglo-Saxon regions followed two distinct approaches in designing the office layout. The British workplace is developer-based and business-oriented, while the Norwegian office is custom-built and user-oriented. This sets the differences in the views and the quality of the workplace environment in these two regions [43]. In the 70s, workers in both places demanded their rights, including thermal control in the workplace. However, the British workers' demands were overruled in the UK, while Workers' Council defended workers' rights in Scandinavia [24]. This decision directly influenced the architectural design of the workplace and the availability of thermal control for occupants. The Scandinavian offices provided temperature control, access to natural light, ventilation and an outside view in personal offices [24], as required by legislation [44]. In contrast, thermal control was not regarded as necessary based on the British work regulations [45] and consequently not reflected in the design of the workplace. In order to accommodate technological advances [46], flexible communication [47], organisational changes [43,48,49], and work and economic efficiency [50,51], the open plan layout was designed in the UK [43]. However, this design was not popular by employees [24], mainly due to distractions [52] and lack of individual climate control [53]. Overall, the context of the two countries [42] and the impact of Works' Council and work regulations influenced their design of the workplace and environmental control [24]. In this study, energy performance and user comfort and satisfaction in two case study buildings in Norway and the UK were compared.

3. Methodologies

Two methodologies are mainly applied to study thermal comfort: experimental chambers and field studies of thermal comfort [54]. De Korte et al. studied the pre-set and preferred thermal and lighting control using an experimental climatic chamber [55]. Kroner studied the impact of personalised thermal control in the daily context of an open plan office [15]. Luo et al. applied field studies of thermal comfort to compare thermal control in two office buildings in different climatic conditions [56]. Although the experimental chambers have the advantage of control over the condition of the experiment and it is possible to limit the variables, their findings often do not apply to the context of daily life [57].

In this study field studies of thermal comfort were applied to investigate user comfort and energy performance of the building when high and low levels of thermal control were provided in the workplace. A cellular plan office layout in Oslo was compared with an open plan office in Aberdeen. In the Norwegian office, every individual was provided with control over an openable window, blinds, door and thermostat, while air conditioning was operating in the background to ensure a standard level of indoor air quality. In contrast, in the British office, displacement ventilation was the main thermal system and limited openable windows and blinds provided control for occupants seated around the perimeter of the building. Majority of the occupants seated further from the windows did not have access to any means of thermal control.

The buildings were built within the last ten years with high quality of standards and insulation and followed the work regulations and particular office layouts of these two countries. Each building was studied for a period of a week during the summer

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