Designing sustainable office spaces – how to combine workspace characteristics with sufficiency strategies

R Fauth¹,³ and M Pieper¹,²,⁴

¹ CG Elementum AG, Haferkornstraße 7, 04129 Leipzig, Germany
² Faculty of Civil Engineering, Chair of Construction Engineering and Management, Bauhaus-Universität Weimar, Marienstraße 7, 99423 Weimar, Germany
³ rainer.fauth@cg-elementum.de
⁴ marianne.pieper@uni-weimar.de

Abstract. Contemporary workspace and office concepts are part of many major commercial real estate projects and have been continuously developed over many years. With a rising awareness for sustainable development, workspace and office concepts are increasingly being considered in terms of their environmental performance. Sustainable design strategies therefore traditionally differentiate between efficiency, consistency, and sufficiency, whereas the latter approach is the least explored in the construction industry. Sufficiency can be described by a user behaviour characterized by frugality and modesty, as opposed to wasteful consumption. Moreover, the strategy of sufficiency is linked to a high and critical awareness of using natural resources and environmental impacts which also affects the built environment. The aim of this paper is therefore to combine these two subject areas in a structured way and derive potentials for the sufficient development of office concepts. Based on a literature review in the field of workspace design and flexible workplace management, design features of office spaces are conceived and compiled according to planning aspects in office concepts based on employee needs. Another literature review in the field of sufficiency in the building sector provides the corresponding structure for the considered sufficiency strategies. Sufficiency measures follow recurring principles for the reduction of resource consumption. Essential principles of impact are identified and presented in this paper. The investigated topic areas are compiled together in a logical model based on a developed mapping framework. This forms the basis for defining sufficient measures that can be derived to sufficiency strategies in the project development of office buildings. The basis of all measures is to strive for a minimum level of resource consumption that is necessary to satisfy the needs of the users and that is considered valuable by them, following the basic idea of the sufficiency approach. The results are validated using an office building in the planning stage. The paper leads to a common understanding and structuring of design features of future office spaces and their environmental impact. Furthermore, the approach provides guidance for concepts on how design features can be considered regarding sufficiency strategies.

Keywords: sufficiency in construction, conceptual framework, sustainable workspaces, sufficiency principles, development strategies
1. Introduction

Problem statement and research objectives. The construction industry is the world's largest consumer of resources and raw materials. 50% of the world's steel production and 3 billion tons of raw materials annually are attributed to the building sector [1]. In Germany, the current real estate stock causes 16% of the total CO₂ emissions [2]. The construction and real estate industry therefore plays a key role in achieving the sustainability goals set by the German government and in the international context. At the same time, the industry is faced with the challenge of meeting global population growth and rising economic output while at the same time conserving resources in construction and sustainably renovating existing buildings. In this context, in addition to residential development, attention should also be paid to the long-term development of office buildings, which must simultaneously meet increasing technical requirements and space demands.

In the light of changing work practices, not only due to the ongoing Covid-19 pandemic, office requirements themselves have evolved and need to be assessed for long-term sustainability in the real estate industry. The most important aspects to consider when designing work environments are functionality, agility, sustainability as well as an increasing focus on the physical and mental well-being of employees, which impact corporate real estate strategies. Planning, monitoring and regularly assessing the space and accessibility needs of businesses can help them respond to their actual resource and energy needs and to be more environmentally sustainable in the urban context.

There are different approaches to the priorities that can be emphasized when considering sustainability, namely efficiency, consistency, and sufficiency. Especially with regard to avoiding rebound effects, sufficiency is considered as an indispensable component for sustainable goals, but there is rare knowledge about sufficiency criteria and indicators due to the difficulty to measure and assess this approach. At its core, sufficiency deals with how consumption can be reduced through various strategies. Comparability between alternatives is therefore difficult due to the lack of quantitative measurability. Consequently, it is more a matter of assessing the impact of various sufficiency measures in combination with an estimation of user behaviour in order to achieve a sufficient adjustment of consumption by controlling behavioural patterns.

The aim of this paper is therefore to examine the evaluation of design features of office types regarding sufficiency based on defined criteria. To overcome this research gap, the following research questions (RQ) are addressed in this paper:

(1) What are important principles for sufficiency in construction and what impact can they have on building design?
(2) How does sufficiency affect the identification of relevant design features and the strategic development of office concepts?

Research methodology. The methodological framework for answering the research questions is shown in figure 1, followed by a more detailed explanation of the steps and the assumptions underlying them.

![Figure 1. Research steps.](image-url)
Due to the research gap described above, it is necessary to create new knowledge that forms the theoretical research framework of sufficiency in construction and the characteristics of office design concepts. This is provided by a semi-systematic literature review. Semi-systematic literature reviews are used to provide an overview of a topic and its research development over time [3]. The main accomplishment of this article is the consolidation of fundamental sufficiency principles in construction as well as design features of office buildings and their implications for generalized employee needs, they must meet. Based on this, the findings of the research are combined in a deductive model. The structure of this approach is therefore in line with a conceptual paper characterized by drawing on multiple concepts and theories from literature [4]. This mapping, explained in more detail in the implementation chapter, serves to link sufficiency principles in construction to the fundamental needs of employees that impact the design of office space. By doing so, new connections between the subject areas are identified and it is revealed what influence sufficiency principles can have and how this affects design measures for real estate companies in the design of office space. For a holistic sufficiency analysis, the resulting outline also addresses the extent to which these measures may have an impact on user behaviour and which risky situations could arise as a result, which must be considered. As a result, it is possible to derive sufficient planning strategies for office concepts. The findings are validated using a design project of an office building in terms of fundamental planning decisions. Finally, the results are discussed and derived to be generalized for future projects. This paper therefore provides a basis to close the identified research gap and to improve a holistic sustainability assessment of office buildings while enhancing employee well-being through various development concepts that meet current office building requirements.

This paper is based on the perspective that an office concept is not planned for a company's own use, but rather from the point of view of a project developer, space must be developed for possible future tenants that meets various requirements. Therefore, the spatial implementation of business processes, which generally provides an important basis for office design, is not considered. In contrast, the focus lies on flexibility, durability, and agility of the concepts. Although the current planning uncertainty caused by the ongoing Covid-19 pandemic is not a primary concern, these basic objectives also address this need and are intended to enable location and company independent working patterns.

2. Research framework

Sufficiency in construction

The general debate on sustainability is many decades old, but the content and expectation behind it have changed continuously. The focus which initially was on protection of natural resources, has widened to a protection of habitat and social values [5]. For this reason, the strategies of sustainable building design have changed equally. In this regard, various sustainability strategies have been developed. Many of them follow the principle of efficiency, consistency, or sufficiency. Efficiency considerations are based on increasing well-being for individual consumers due to technological improvements, while reducing the environmental impact. Measures are assessed and evaluated in terms of their relationship or ratio between performance and effort. A key advantage of this is the quantitative evaluation of alternatives as a basis for decision making. Regardless of the breadth of content, efficiency strategies were and still are very common as a design approach and measurement concept for sustainable design in construction. In contrast, research has shown largely that such approaches can be ineffective, due to rebound effects that offset or even overcompensate efficiency savings [6].

Strategies of consistency aim at finding alternative ways to make qualitative changes in production and consumption patterns, for example through resource substitution and alignment with natural resource streams. Individual consumption would then be more diverse, innovative, and consistent with environmentally friendly products [6]. In the construction industry, this is for example possible using recyclable building materials and renewable energies, although these are also contradicted by the increased space consumption per capita [7]. In both approaches, efficiency and consistency, advantageousness can be demonstrated by comparing different, alternative solutions with each other and with ordinary approaches. The sufficiency approach is distinct from this. Fundamental to this approach
is the question of how much economic growth our ecosphere can tolerate and how moderate and reduced consumption can be an effective sustainability strategy. Studies have shown that there is a large unexploited ecological potential here to counteract the rebound effects of the previous strategies. Nevertheless, such approaches have rarely been used so far, as this requires adapted, critical, and value-oriented user behaviour, which in turn demands acceptance of such measures, which has been lacking so far. [8]

For example, rising heating energy and electricity consumption per capita due to greater prosperity may be addressed through incentives or other strategies to reduce space, heating, cooling, and ventilation. It must be made transparent to consumers where the savings potentials lie, how high they are and with which behavioural changes they can be generated. Likewise, strategies must be developed that influence and control this sufficiency behaviour from the outset. In some aspects, it is possible to roughly show consumers these savings potentials, for example, that one-degree lower room temperature in a new building generates heating energy savings of about 10% [8]. Studies have also shown that residential tenants achieved significant savings in the consumption of heating energy, electricity, and hot water through energy consultations, without having to make structural changes to the building [8]. However, these studies are mostly based on residential buildings; there are hardly any holistic studies for office buildings and concrete effects of sufficiency measures on structural or technical changes in construction. Furthermore, there is a lack of evaluating design features regarding sufficiency.

The difficulty, unlike with efficiency and consistency strategies, lies in the measurability of effects and the quantitative evaluation of alternatives since user behaviour must be factored in as an uncertainty. A functional unit used as a baseline for efficiency and consistency measurements does not meet the goal of sufficiency. Instead, different levels of comfort and service must be used as a basis for consideration. However, the different basis leads to challenges when comparing sufficiency strategies. For this reason, the literature usually defines overarching sufficiency goals [7, 9]. It was found that these show a wide range of targets, criteria, and indicators, which can be categorized. Building on this insight, these were traced back to fundamentally applicable principles and generalized. The following sufficiency principles were derived and compiled from the semi-systematic literature review for the present study:

**Table 1. Sufficiency principles.**

| Principle   | Explanation                                                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Simplicity  | A functional design with minimalistic elements to prevent unnecessary functions and errors in operation that cause high resource consumption |
| Density     | A high density of use reduces building structure and infrastructure for lower resource consumption                                         |
| Durability  | High qualitative durability reduces the need for replacement and simplifies reuse                                                             |
| Adaptability| A high qualitative adaptability reduces consumption due to adjustments of needs                                                              |
| Locality    | Local products and services save logistical resources                                                                                       |
| Mutualty    | Sharing resources reduces the absolute consumption                                                                                          |
| Comprehensibility| Better understanding through awareness and information supports conscious change in user behaviour                                 |

These principles will be examined for intersections with holistic office design for sustainable development of office buildings, for which the following chapter provides the theoretical foundation. Conceptualisation of office space. The working environment in the office has undergone significant changes over time and in line with social and global developments. New working styles, emerging technologies and changing lifestyles require the exploration of the positive and negative effects of different office layouts and the extent to which they meet the psychological and organizational needs of
today's generation of workers [10]. Over the years, three main patterns of office organization have evolved: cellular offices, open-plan offices, and activity-based offices.

A common design in the past were cellular offices, usually arranged along a corridor with individual offices or shared offices, surrounded by walls and separated from common working space and other offices [11], making communication and collaboration more difficult [12]. Studies have shown that cellular offices can promote concentration, privacy, and personal control over the daily work routine as well as an increased wellbeing [12], and an overall job satisfaction [13]. Nevertheless, cellular offices are more difficult to redesign and adapt to changing company structures or a higher number of employees, which is accompanied by higher space consumption and higher fixed costs. For this reason, this office layout does not comply with the principles of sufficient planning. In contrast, open office concepts are characterized by large spaces lacking physical barriers, filled with multiple desks in different arrangements [14]. Advantageous to open offices is a higher space efficiency and lower maintenance costs [14], improved communication and employee interaction which can lead to increased work performance and organisational productivity [13]. On the other hand, there are some considerable disadvantages, such as distractions, noise, lack of privacy and personal control, insufficient storage space and a poor indoor climate [13].

To overcome these disadvantages while taking advantage of the open structure, the concept of the activity-based office (ABO) has been introduced. In ABOs, workspaces are typically not assigned to individual employees, but they are used based on the activity being performed and the associated requirement [10]. These are non-territorial offices with a variety of open and enclosed workspaces to best support the various activities of employees throughout the day [15]. There can be multiple activities that employees need to accomplish, which can be clustered according to [16] into five categories: (1) collaboration, (2) individual work, (3) formal meetings, (4) conversations, (5) other. The corresponding activities should be performed in various types of spaces that are designed and equipped differently to achieve the best possible performance according to their category. Mapping activity patterns is therefore essential to determine the type and scope of the required office space.

Depending on the way of implementation and company size and culture, both advantages and disadvantages can arise in this concept and research shows inconsistent results on that [17]. Common disadvantages are a lack of privacy and concentration, the neglect of psychological needs such as personalization through desk-sharing [17] as well as poorer indoor climate and a lack of storage [15]. However, ABO concepts can generally be attributed with higher employee satisfaction and productivity, increased autonomy, cost reduction due to space efficiency, special aesthetics, and improved ergonomics as well as a better communication and interaction and the possibility to overcome the mentioned disadvantages with an increase of enclosed workspaces [17]. Based on these benefits and the underlying perspective of this elaboration, a project developer for different tenants with different demands that need to be considered, the design concept of activity-based offices is suitable and the focus of further considerations in this paper. A fundamentally more economical space planning is also in line with the concept of sufficiency.

In addition to mere space considerations, holistic office planning must consider the various needs and preferences of users, which can be addressed through interior design or space configuration. A distinction can essentially be made between physical, functional, and psychological needs. Physical needs address the ambient factors, functional comfort refers to the extent to which the environment supports the employee’s task and performance while psychological needs as a third component consider basic human needs which can have a positive impact on overall well-being at work [13]. Table 2 specifies these needs based on the work of [13] and supplemented or concretized.

Table 2. Employee needs in offices.

| Physical needs                      | Functional needs     | Psychological needs            |
|-------------------------------------|----------------------|--------------------------------|
| Climate comfort                     |                      |                                |
| - Air temperature and quality       | Concentration        | Privacy and autonomy           |
| - Air circulation                   | Communication        | Social interaction             |
| - Humidity                          | Productivity         | Feeling of belonging and appreciation |
| Control over climate comfort        | Efficiency           | Territoriality                 |
| Visual comfort                      | Proximity of co-workers | Personalization               |
| - Natural and electric light        | Space                | Status expression              |
| Noise protection                    | Storage space        | Aesthetics                     |
| Spatial acoustics                   | Ergonomics           | Relaxation                     |
|                                     |                      | Health, safety and well-being |

This overview serves to briefly present the different planning dimensions that must be considered to provide efficient and effective spatial implementation of processes. From the literature review, it can be deduced that the fundamental goal of office planning is to implement strategic structures that avoid unnecessary movement of materials, create healthy and comfortable surrounding conditions for employees, while providing opportunities for communication and collaboration.

3. Implementation

In order to answer the research questions raised at the outset of this work, the two areas of research investigated are compiled in the following in a structured manner. Figure 2 shows the approach underlying the mapping performed to derive a coherent model for sufficient office design.

As mapping activity patterns is essential to determining the type and amount of office space needed, all categories of an ABO (see chapter 2.2) are assumed to be fundamental in this consideration. In order to specify the requirements for these different spaces in more detail, physical, functional and psychological user needs were defined (see table 2) according to the work of [13]. In this way, the findings of the literature research on workplace design were compiled. The incorporation of sufficiency takes place through the assessment of seven main principles synthesized through the literature review (see table 1). By merging them with the requirements for office space design, the result of the mapping is a model that illustrates interdependencies between the areas under investigation. Based on this, it is possible to derive sufficiency-based design measures for the planning of office concepts. In order to take
a holistic view of the sufficiency approach, effects of these measures on user behavior are anticipated. As it has been shown through the literature review that it is difficult to quantitatively assess these measures and effects, risk positions that may occur are estimated. Finally, intelligent development strategies for an ABO that serve to accomplish sufficiency principles can be derived.

The presented approach allows it to investigate building adaptations in general, not component based. This mapping can be seen as a guide that provides decision support for planners to derive sufficient design measures for office planning strategies. Consequently, it is possible to answer the RQ (1): What are important principles for sufficiency in construction and what impact can they have on building design?

4. Validation

The validation is done on the basis of application examples. To illustrate and validate the application of the model developed, two specific needs are selected and analyzed based on the proposed conceptual framework (figure 2). This makes it possible to develop specific measures and to derive development strategies based on them. In this way, the second research question is answered: How does sufficiency affect the identification of relevant design features and the strategic development of office concepts?

Fundamentally, the occupancy planning and layout is oriented towards the organization of various office activities, thus includes the design of all five categories of an ABO. Consequently, employee needs may vary slightly in different activity-based areas. The methodology presented in this paper will be validated and illustrated using the exemplary physical need for climate comfort and noise protection. The climate comfort of office spaces is a function of individual personal conditions and space conditions [18]. This need is interesting to investigate as dissatisfaction with climate comfort can have a negative impact on productivity, which should be avoided. The same applies for noise protection. Furthermore, since it is a common criticism that the indoor climate and noise level in ABOs is not very satisfactory in the open spaces, the planning and management of this in the operational phase is even more important. Relevant indicators of climate comfort that must be considered for this purpose are the operating temperatures derived from air and radiation temperatures, as well as air velocity and humidity.

To derive sufficiency approaches and suitable measures, the sufficiency principles are linked to the climate comfort indicators through the above-mentioned mapping framework. The allocation is described according to the seven identified sufficiency principles. Looking at interdependencies by mapping patterns provides a logical model that contributes to systematizing the search for sufficient measures. The mapping process can be guided and accelerated by repeatedly answering explicit questions about the isolated relationship between the elements under consideration, for example:

- What technical solution based on the principle of simplicity is sufficient to achieve climatically comfortable operating temperatures?
- What technical solution based on the principle of density is sufficient to achieve climatically comfortable operating temperatures?
- …

Table 3 shows an example of the results of mapping the interdependencies between sufficiency in construction and climatically comfortable operating temperatures as well as noise protection, exemplified by the principles of simplicity, comprehensibility, density, and adaptability. By systematically looking at the correlations, sufficiency measures are identified and examined for their adequacy. It shows that multiple measures are possible for each principle.
Table 3. Exemplary mapping of interrelationships for climate comfort and noise protection.

| Sufficiency principle | Interdependencies | Sufficient design measure | Adaptive behaviour |
|-----------------------|-------------------|--------------------------|--------------------|
| **Climate comfort**   |                   |                          |                    |
| Simplicity            | Higher design indoor temperatures in summer reduces cooling load and technical systems to provide it | Cooling system with higher design temperature | Increased adaptation of summer clothing |
| Simplicity            | Lower design indoor temperatures in winter reduces heating load and technical systems to provide it | Heating system with lower design temperature | Increased adaptation of winter clothing |
| Simplicity            | Manual window ventilation can reduce the design and number of technical systems | Window ventilation | User interaction for air quality control |
| Comprehensibility     | Information on changes in energy consumption due to the user adjustment of the indoor temperature can influence user behaviour in the sense of sufficiency | Energy consumption information panel in combination with temperature control devices | Paying attention to information provided before setting the indoor temperatures through a previous energy consultation and pointing out potential savings |
| **Noise protection**  |                   |                          |                    |
| Density               | Reduction of the component mass of walls and ceilings has an influence on sound insulation, area efficiency and the use of resources | Lower ceiling and wall thickness, if other functional requirements allow this | Choice of workplace depending on noise level and required concentration level |
| Mutuality             | Reduction of solid and lightweight interior walls has an influence on noise level between workplaces, area efficiency and the use of resources | Reduction of interior walls and material selection of floor and wall coverings with good sound absorption values for rooms where it is required | Adjustment of the interior and room furniture to meet sound insulation requirements |
| Adaptability          | Adaptation of users to different room acoustics depending on the current work activity | Phone boxes for concentrated work | Place selection in ABO according to activity, Earphones |

The sufficiency measures presented for achieving convenient climate comfort include adjusted design temperatures in winter and summer and the possibility of window ventilation. Based on these considerations, supporting measures in the sense of sufficiency could be examined in further planning steps from architects and engineers, such as the consideration of improved solar protection and moisture-regulating materials that increase thermal comfort despite adjusted design temperatures of the systems. The effects on user behavior and therefore social implications are comparatively modest. Similarly, the
risk to user acceptance associated with the measures described is estimated to be low for the target user group envisioned in the project.

Sound insulation is often the reason for massive constructions and greater ceiling and wall thicknesses, which use up resources and increase environmental impacts, such as greenhouse gas emissions, and reduce usable space. A reduction of soundproofing-related heavy constructions can be an option in various circumstances if users bring a degree of flexibility and are made aware of alternative soundproofing measures.

Therefore, the sufficiency measures described can be well combined in a development strategy if they do not conflict with other building requirements. A key point in the analysis is the anticipation of the required adaptive user behavior, which can have an influence on the demand as well as the user acceptance of the space provided. Addressing this must be part of the derived planning strategy. In particular, the adaptability of the users according to their current activity corresponds not only to the idea of sufficiency but also to the basic concept of an ABO and can therefore be combined well.

5. Concluding remarks
This paper attempted to investigate interdependencies between the design of office concepts and sustainability strategies. Essential for this work was the consolidation of principles for the sufficiency approach in construction that allows to derive different measures according to them. The combination with essential user needs relevant to the design of office concepts pursued an interdisciplinary approach and integrates main research streams in this field. A basic approach for the strategic development of sufficiency-based development strategies was created through the mapping framework presented. This is generic and could be adapted or extended to other areas of interest. However, it provides basic insights into the topics studied and allows generalizations to be made. The model developed can be used in project development to derive sufficiency-oriented development strategies and thus closes the identified research gap in this area. The authors' findings have implications for multiple stakeholders, both in the planning and design of projects in practice and for researchers and companies in the field of sustainability in construction and office design. In addition, individual factors of specific projects can and must be considered in a supplementary manner, which was not the aim of this study due to the assumption of a high-level perspective. The developed framework will be integrated and further verified in a case study to further advance the application of the sufficiency approach in construction as a complement to efficiency and consistency. It will help developers and researchers explore the impact of sufficiency measures in the context of employee needs and how to meet those requirements. A derivation of floor plan layouts and building typologies as well as economic implications is feasible based on this. An application to other asset classes such as residential or retail would also be conceivable but would require the definition of different specific user needs in the first place, following the same general approach.

The future research agenda can anticipate several issues that can contribute to a holistic view of the research area. Primarily, the current assumptions are based on a contemporary view, which refers to the requirements for office concepts as well as the dimensions and effects of sufficiency. With extended research on both topics, the presented mapping of these two subject areas also adjusts and extends gradually. The impact of the Covid-19 pandemic was not considered in detail. This is particularly difficult because forecasts, for example about future home office regulations or desk-sharing rates, are not clear. Planning solely on this basis is therefore not a long-term option, although activity-based offices still provide a good framework for responding to pandemic-related developments and adjustments. Regarding these areas, it should be noted that not all company structures and cultures appreciate or require such a division of space. If the development of a company's own office space should be the focus of the considerations, an alignment of the spaces in harmony with the company structure and culture is needed to achieve certain organizational and employee outcomes. In this context, it should be noted that the furnishing of the office space is not considered in this paper and can be included in further work as well as additional services and the technological equipment. In addition, the effects of specific measures on user behavior must be analyzed. Similarly, to the studies on energy
consulting in the residential sector, such effects are to be investigated in office buildings. It is expected that performance measurements and comparative best practice studies will provide further insight. Due to the ongoing debate, the sustainable development of buildings is becoming even more important, and the presented framework can contribute to that.

References
[1] World Economic Forum 2016 Shaping the Future of Construction: A Breakthrough in Mindset and Technology (Geneva) p 11
[2] Presse- und Informationsamt der Bundesregierung 2022 Bauen und Wohnen [internet] Available from: https://www.bundesregierung.de/breg-de/themen/klimaschutz/klimafreundliches-zuhause-1792146
[3] Snyder H 2019 Literature review as a research methodology: An overview and guidelines. J. Bus. Res. 104 pp 333-339
[4] Jaakkola E 2020 Designing conceptual articles: Four approaches. AMS Rev. 10 pp 18-26
[5] Fauth R 2017 Entwicklung eines Modells zur Bewertung der Nachhaltigkeit von Bestandsgebäuden [dissertation] (Neubiberg: Universität der Bundeswehr München) p 7
[6] Schäpke N and Rauschmayer F 2014 Going beyond efficiency: including altruistic motives in behavioral models for sustainability transitions to address sufficiency Sustainability: Science, Practice and Policy 10:1 pp 29-44
[7] Over M, Zimmermann P and Brischke L-A 2020 Wie muss man bauen, um suffizientes Wohnen zu ermöglichen? Proc. 26th Interdisciplinary Scientific Conference Mittweida (Mittweida: Hochschule Mittweida) pp 204-209
[8] Schoof J 2014 Less is more – or is it? DETAIL Green 02/14 pp 16-21
[9] Steffen A and Fuchs M 2015 Weniger ist weniger - und anders db deutsche bauzeitung 06 pp 26-30
[10] Zamani Z and Gum D 2019 Activity-based flexible office: Exploring the fit between physical environment qualities and user needs impacting satisfaction, communication, collaboration and productivity J. of Corporate Real Estate 21:3 pp 234-253
[11] Ullman F and Boutellier R 2008 Physical layout of workspace: a driver for productivity in drug discovery Drug Discovery Today 13 pp 374-378
[12] Rasheed E O, Khoshbakht M and Baird G 2019 Does the Number of Occupants in an Office Influence Individual Perceptions of Comfort and Productivity?—New Evidence from 5000 Office Workers Buildings 9:3 pp 1-14
[13] Budie B, Appel-Meulenbroek R, Kemperman A and Weijser-Perree M 2018 Employee satisfaction with the physical work environment: The importance of a need based approach Int. J. of Strategic Property Management 23:1 pp 36-49
[14] James O, Delfabbro P and King D L 2021 A Comparison of Psychological and Work Outcomes in Open-Plan and Cellular Office Designs: A Systematic Review SAGE Open pp 1-13
[15] Brunia S, De Been I and van der Voordt T J.M. 2016 Accommodating new ways of working: lessons from best practices and worst cases J. of Corporate Real Estate 18:1 pp 30-47
[16] Rothe P 2017 The rise and rise of Activity Based Working: Reshaping the physical, virtual and behavioural workspace (London: Leesman)
[17] van der Voordt T J.M. 2004 Productivity and employee satisfaction in flexible offices J. of Corporate Real Estate 6:2 pp 133-148
  Keller B 2010 Pinpoint: Key Facts + Figures for Sustainable Building (Basel: Birkhäuser) p 11