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Jylhä, Tuuli; Danivska, V.

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Preface

We invite you to read, learn, and be inspired by the proceedings of the 22nd EuroFM Research Symposium, organized within the 28th EuroFM Facility Management Conference, which will take place from November 9th to 11th, 2023, in Istanbul, Turkey.

The conference theme, 'Shaping the Next Generation of FM,' emphasizes the need for Facility Management (FM) to adapt to transformations in education, research, industry, and the broader FM community. These transformations encompass innovations and developments in FM, leadership and management practices, and sustainable FM. Aligned with this theme, the papers included in the proceedings focus on the topics of digitalization, circularity, and learning spaces.

This proceedings contains a total of 16 papers, all of which have undergone a double-blind review process. We extend our heartfelt gratitude to the members of the scientific committee and the best paper committee for their dedication and expertise throughout the review process. Your valuable contributions, constructive feedback, and insights have not only ensured the originality of FM research but have also sustained the validity of the research presented in these proceedings.

We are deeply thankful for the contributions, commitment, and passion demonstrated by the authors. We are very proud that the authors have chosen to share and elevate their research findings at the EuroFM Research Symposium 2023. We are happy that the EuroFM Research Network has the privilege to support the advancement of cutting-edge FM research. Thank you for your trust and contribution!

A special recognition goes to the local host, Prof. Dr. Harun Tanrıvermi, and his team from Ankara University for their invaluable local support, knowledge, and, most notably, their enthusiastic and genuine investments in advanced FM research.

We would also like to express our gratitude to TRFMA Türkiye Facility Management Association for organizing the 28th EuroFM Facility Management Conference and the 22nd EuroFM Research Symposium in the beautiful capital of Istanbul. Furthermore, our appreciation goes to Danica Widarta for once again contributing her outstanding design skills to create a beautiful cover and layout for the proceedings. Her design not only enhances the reading experience of the proceedings but also signifies the importance of the conducted research.

The proceedings are intended not only for FM researchers but also for educators, students, practitioners, and the broader FM community. The EuroFM Research Network has adopted an open-access research policy to ensure that everyone can benefit from FM research. We hope you will find the proceedings both interesting and useful for your FM responsibilities.

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Chair of the Scientific Committee
Research Chair, EuroFM

Vitalija Danivska
Co-Chair of the Scientific Committee
Conference Chair, EuroFM

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Across the Boundaries of Epistemic Knowledge: Future Shaping Through Digitalisation Frameworks for FM

Ghalandar, T.[1], Hansen, G.[2], and Lindkvist, C.[3]

ABSTRACT

Background and aim - Currently, new opportunities and potentials arising from digitalisation and digital twins do not stretch far enough into the future of the built environment, particularly for FM. Better visioning of the future is required to prepare FM practice to adopt these opportunities and potentials for innovation and to react to urgent sustainable requirements.

Methods / Methodology - This work is part of an ongoing research project on the delivery of digital twins to facility management. Within this article, an exploratory approach is used to conduct a review of the literature regarding digitalisation and the use of digital technologies such as BIM and Digital Twins across the boundaries of epistemic knowledge. Furthermore, framework documents for digitalisation in the UK and Norway have been reviewed to identify the key aspects by which technology integration is geared towards the future. The main theoretical frameworks of this study are innovation and knowledge management.

Results - Digitalisation and digital technologies' integration represent a huge potential to bridge the gap between early phases and FM. Digitalisation guided by frameworks can help shape the future of the built environment, improving the dynamics of FM integration and practices within the building lifecycle. However, the process is highly reliant on better communication and collaboration across the different disciplinary boundaries, to reap the benefits of digital innovations within the sector.

Practical or social implications - Future making through the interlink of digitalisation and sustainability can lead the industry to a future where technology is fit for purpose and FM data and sustainability considerations are an integral part of the projects. This can also provide an outline for the identification of possible gaps and drivers for innovation within the topic.

Type of paper - Research paper

KEYWORDS

Future Making, Digitalisation, Sustainability, Knowledge Boundaries, Future of FM.

INTRODUCTION

Digitalisation and the weak link between early planning and design towards use and FM

Over the past 20 years, the potential for BIM and more recently Digital Twins to manage data and information across the full life cycle of buildings has been discussed. These tools are expected to help with collaboration in projects, however, their integration and implementation have often been more imagined than realised for FM. This is partly due to the persistent "tension" that exists between new

[1] Department of Architecture and Planning, Norwegian University of Science and Technology, toomaj.ghalandar@ntnu.no
[2] Department of Architecture and Planning, Norwegian University of Science and Technology
[3] Department of Architecture and Planning, Norwegian University of Science and Technology

technologies that are to be introduced and the established practices of actors within the industry (Dossick et al., 2019). Although technologies such as BIM and Digital Twins are viewed as enabling collaboration and communication, there is a lack of coalescence between the organisational and technical aspects of technological innovation and integration for which industry frameworks can be a mediator. However, frameworks do not often seem to address the collaboration and integration challenges that exist within the industry, and this creates a gap. Integration is not just a technical phenomenon, and it is reliant on those practices understanding based on knowledge boundaries which the frameworks often miss.

Communication and collaboration within Architecture Engineering Construction/FM (AEC/FM) industries rely on diverse stakeholders working at different stages of the building project which is difficult to sustain from a lifecycle perspective (Rezgui et al., 2011). Information communication technologies are often viewed as a stable referent (Whyte et al., 2016). Indeed, such technologies are viewed as a tool for building lifecycle integration of information and data particularly that bespoke to the operation and management of the built asset. Digital technologies such as BIM and Digital Twins offer opportunities to link project information to facility management practices as well as to mediate the communication process (Lindkvist, 2015, Araszkiewicz, 2017). The use and integration of BIM and Digital Twins require standards and clear frameworks through which the industry can benefit from their use especially in building operation and management practices (Qiuchen et al., 2021). The form of such frameworks and with it the use of digital technologies need to be in line with the scenarios by which operation and management tasks are executed in a built asset (Qiuchen et al., 2021). This use of technology in the processes has the potential to have a meaningful impact on FM practices with the tangible benefit of reducing costs of maintenance in the built asset (Atkin and Brooks, 2015, Marocco and Garofolo, 2021).

The underpinning of technological innovation and integration is the technological culture within the industry. “Technological culture” shapes society and the “sociotechnical” dimensions that exist within it (Bijker, 2009), and any shift in that culture can bring transformative impacts with it. Such culture is linked to the nature of the projects in the construction industry. The characteristics of construction projects include an organisational context as well as inter-organisational dynamics shaped by collaboration and driven by communication (Harty, 2005). Managing knowledge across such boundaries of the organisations is inherently challenging (Carlile, 2002). As knowledge that is often assigned to a “function” is seen as specialised knowledge related to that function, working across knowledge boundaries is problematic (Carlile, 2002). This requires an understanding of the specialisations that otherwise have little in common.

The aim of this article is therefore twofold. Firstly, to elaborate on digital innovation and technology integration based on knowledge boundaries existing in the AEC/FM industry. Secondly, to reflect on knowledge integration within boundaries of the project and FM through a comparison of existing frameworks on digitalisation in the UK and Norway and the future vision that they carry.

Digital innovation with disruptive knowledge boundaries

Digital innovation is a process that follows a dynamic pattern where technology, actors and their practices are not separate. The innovation process can be best defined based on the premises of the environment and the context in which these elements are being simultaneously considered (Papadonikolaki et al., 2022). In such a dynamic context multi-actor collaboration and the interactions of the users of technology and actors are reliant on the modes of performance and communication that are either defined by the industry or based on the environment itself (Dossick and Neff, 2011). Frameworks are often used to define industry modes of performance and communication, but digitalisation is often backgrounded in these frameworks. At the same time, digitalisation in the construction industry is a continuous process within a social context where collaboration is key. The continuous process of digitalisation is fluid by nature, which is opposed to the word "construction" conveying a meaning that something is "fixed" (Law, 2008). Although technology application and integration happen in a building that is physically static, the nature of the project, its associated organisations and the building itself is of a "becoming ontology" (Dossick and Neff, 2011). Digital innovation presents a new set of circumstances and sociotechnical challenges that need adaptation from both people and organisations and is less "bounded" than just innovation (Papadonikolaki et al., 2022). The crossing of boundaries from construction projects to FM have often been loosely connected. Facility management has been detached from the earlier stages of the projects, with the industry stakeholders not engaging FM professionals enough in the earlier stages (Atkin and Bildsten, 2017). Lack of engagement also extends BIM implementation leading to facility management which is viewed as behind design and construction stages for BIM consideration (Ashworth et al., 2019).

Technological innovation can either be seen as "disruptive" or "sustaining" based on the type and thus can influence the industries and market accordingly (Drew, 2006). Building Information Modeling (BIM) and Digital Twins are often viewed as game changers for the FM discipline (Becerik-Gerber and Rice, 2010, Bröchner et al., 2019), but we have yet to see the impact. This has not limited the many actors within the built environment who view BIM as necessary to consider in their working processes (Papadonikolaki et al., 2019). Technologies such as BIM inherently require actors to collaborate and communicate. They need to be open and adhere to new methods of working and make decisions based on collaboration (Dossick et al., 2019). This type of collaboration has been challenging for AEC/FM stakeholders and actors, as they often aim to use the same data but apply it in different knowledge boundaries. The discourse around technology implementation is twofold. One is based on it being a tool and the other is based on the context in which it is implemented (Sackey et al., 2015) . Digital innovation presents less definitive form of relations between the actors and is by nature less restricted and contained to a certain subject or field of expertise (Papadonikolaki et al., 2022). The multiplicity of understanding of innovation across actors is based on their epistemic knowledge(Whyte and Nussbaum, 2020, Ewenstein and Whyte, 2009) which creates tangible and intangible boundaries between actors at different stages of the life cycle. Communicative processes help bring insights and interests of all stakeholders and facilitate collaboration in the long run (Lindkvist et al., 2019). This is important as innovation happens through crossing the boundaries of collaborative knowledge transfer where several stakeholders with different expertise are involved (Caccamo et al., 2023). The concept of "boundary object" is key to knowledge integration and learning for collaborative processes in technological innovation (Caccamo et al., 2023). Boundary objects enable knowledge integration and collaboration based on accepting the diversity of the specialised knowledge among diverse stakeholders (Caccamo et al., 2023). Such collaboration relies on knowledge integration in the innovation process without the need of each stakeholder having to gain full understanding of others fields of knowledge to be able to cooperate (Caccamo et al., 2023).

The implementation of new technology and "IT systems" emphasise "innovation" and "strategic" aspects for implementation (Sackey et al., 2015), but leads to uncertainties of framework definitions in the industry. Technologies such as BIM are considered a collaborative tool that have the potential to be used in the context of overlapping "boundaries" of different disciplines and multi actor environments (Dossick and Neff, 2011) and so is the ambition with utilisation of Digital Twins in the industry. The changes that follow implementation of digital technologies such as BIM in organisations presents a dichotomy of opportunity and challenge in technology use (Sackey et al., 2015), which building industry have attempted to resolve within technology development frameworks. Frameworks offer a tangible boundary where different disciplinary knowledge can be prioritised, and visions of technological innovativeness can be expressed and set in motion. Such frameworks are often underestimated in implementing new technologies for future oriented uses such as that from projects to FM. Therefore, the question for this research is how collaboration and communication are embedded in building industry digitalisation frameworks for the future given their importance for knowledge transfer in innovation.

Imagined futures for digital adoption within organisational learning and knowledge management boundaries

Digital technologies evolve continuously. Technology is constantly changing which is in opposition to the traditional nature of the construction industry (Klinc and Turk, 2019, Newman et al., 2021). Learning processes and growing competence in new technologies in organisations is a complex phenomenon and is at times in contradiction with further motivation for innovation (Levinthal and March, 1993). However, in order to innovate practices must learn new competencies and change. Within the AEC/FM industry, there is a co-dependency across disciplines use and implementation of life-cycle information management systems such as BIM and digital twins, actors who work in different timelines and contexts (Whyte et al., 2016). Learning in organizations is distinguished by its collaborative nature, something that happens in communities of learning and therefore is not isolated to processes that are bespoke for a single individual (Brown and Duguid, 1991).

Woolgar (1990) more than 30 years ago considers the boundaries and characteristics of technologies in terms of the impact of the user as being "uncertain" and unclear weighing up technology as something that is bounded or a continuum. This creates new ways of thinking about the boundaries of technologies embedded and influencing building use and non-use where a building goes from as-designed, as-built but 'as-operated' never comes to be as this is a continuum. There is already a "moral order of representation" in how a building is managed and operated with all the human and nonhuman entities within it (Woolgar, 1990). This "moral order" is then impacted once new technologies are introduced into the currently existing relationships (Woolgar, 1990). The moral order of representation is essentially defined as the entities, their characteristics or the associated relationships between the entities and the degree to which they are deemed as bounded (Woolgar, 1990). Furthermore, we can discuss the role of technologies in carrying out tasks, and to what degree we consider them as "capable" in the tasks being carried out (Woolgar, 1990). While this work is more than 30 years old, the view of technology being capable and carrying out tasks is echoed in current blue-sky thinking of technology innovation (Lindkvist, 2015) and the potential digitalisation for tomorrows future (Bröchner et al., 2019). The slow evolution of technology innovation questions when such futures can be realised and what is holding it back. In order to study future-oriented technology evolution, one must consider the role of imagination in the introduction and use of technologies. Here the issue is that imagination and innovative thinking on the future of technologies and their use could be limited as imagination itself is limited (Westrum, 1991). The limits of imagination ultimately set the boundaries for technological innovation. In the built environment sector, the "building user" is seen as integral to the design process and "imagined user" helps designers to target their design work (Ivory, 2013). Such approaches of the 'imagined user' offer tangible meaning that could be extended to FM.

METHODS

This paper has been developed based on an exploratory review of the literature on the digitalisation of the AEC/FM industry and a preliminary study of digitalisation frameworks in relation to the future of facility management. This has been done through the lens of innovation, collaboration, as well as knowledge management. The review mainly focuses on the management aspects of digital innovation and technology integration in organisations with a particular focus on technologies that either have been or are expected to be geared towards building operations and the management phase. Such technologies include but are not limited to Digital Twins and Building Information Modeling (BIM). The literature review has been an exploratory process which has begun at the start of the PhD research project in august of 2022 and has continued until this day.

The process of the review has had a point of departure which included reading articles of high academic quality and standards introduced and recommended to the author either by academic experts or by conducting searches in google scholar. The process has also included cited reference searching method. The keywords and phrases that that have been used for the searches include: "Digitalisation", "Future of Facility Management", "Building Information Modeling (BIM)", "Digital Twins", "Knowledge Management" and "Innovation in Built Environment" the search terms have been organically tweaked and modified as the scope of topic has become clearer. The review process continues with the study frameworks, roadmaps and strategy documents for the digitalisation and sustainability of the AEC/FM industry in Norway and the United Kingdom. They have been selected based on recommendations by industry and academic experts as well as conducting searches on the web; the timeline for consideration has been between the years 2008 and 2023 but the framework and strategy documents used for writing this paper are mainly from 2015 onwards to allow reflecting on more recent documents that are still applicable today. Norway and the UK are interesting to consider because they have considerably progressed in their outlook for digitalisation of the building industry but different in ways. In the UK, the government mandated BIM in all public projects, where the same steps were not taken in Norway, but BIM has progressed into project practices.

The Norwegian documents are primarily developed by the building industry and include organisations such Norsk Eiendom (Norwegian Property), Grønn Byggallianse (Green Building Alliance), Byggenæringens Landsforening (The National Association of the Construction Industry). Similarly, the study of the documents from the United Kingdom have included organisations such as Royal Institute of Chartered Surveyors (RICS), British Standards Institution (BSI) as well as Centre for Digital Built Britain (CDBB) and UK BIM Alliance. The overarching themes of the literature review has been categorised and visualised below:

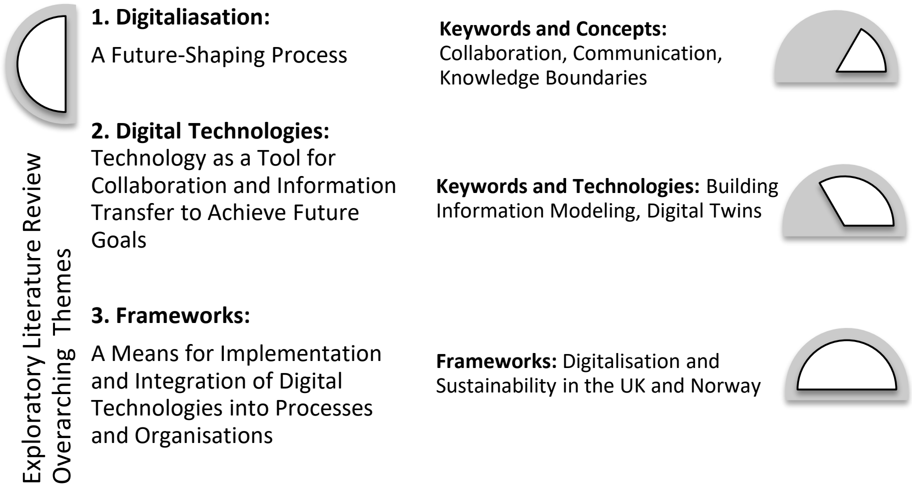

Figure 1 Exploratory literature review themes.

The source for this review consists of documents provided by academia, the industry, and the government. The review of the frameworks has been a preliminary study for this paper, touching upon the key subjects and challenges that are raised in the selected documents, however this work is currently continuing with the analysis of a larger selection of documents the results of which can be published in the future. The search has also been limited due to these documents tend to be tied to specific think tanks and organisations and there is no one-stop-shop of attaining these documents, which may mean that there may be other documents that have not been included.

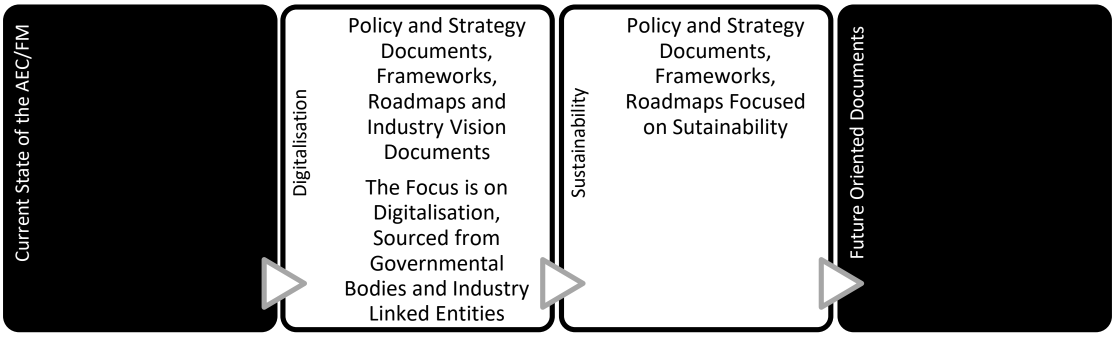

Figure 2 Frameworks of digitalisation in the UK and Norway.

Frameworks for driving future visions in Norway and UK

The following examines how frameworks for digitalisation and sustainability can support the building industry in crossing boundaries between different disciplines. Norway and the United Kingdom strategies for AEC/FM digitalisation and sustainable future are examined through published roadmaps, visions, frameworks and policy documents since 2015. The following presents some initial results that illustrate how these frameworks provide a possible vision for the industry to aspire to.

Crossing boundaries between digitalisation and sustainable as future trends

The Norwegian future vision in "Digital Roadmap 2.0" and "The Property Sector's Roadmap towards 2050" have a particular focus on sustainability as a goal in line with digitalisation. The documents refer to "optimal goals" such as resource efficiency and politically driven goals in line with the current aspirations of Norwegian society regarding the green shift and recognising major challenges such as climate change and limited natural resources (Byggallianse and Eiendom, 2016). Norway's climate act came into force in 2018 setting targets for 2050, which include "visions" and "scenarios" for the real estate and construction sector in line with the "national and international commitments" to climate naturality, eliminating environmental impacts and closing material loops by 2050 (miljødepartementet, 2022, Byggallianse and Eiendom, 2016). This is then further complemented with recommended measures for building owners to prepare themselves and their portfolio of assets for the future (Byggallianse and Eiendom, 2016). The emphasis on environmental measures in a digital roadmap indicates that these two components are considered equal in future preparations for AEC/FM. Within the Norwegian context, it is recommended that the industry takes a business mindset towards the topics and "anchor" the topic both to the business plan as well the top management (Byggenæringens-Landsforening, 2020). Goals of the digitalisation both regarding the increased efficiency in business and the sustainability should be set and the whole organisation should be mobilised and not just specialists (Byggenæringens-Landsforening, 2020). In this process if business models need to change, they should as basing digitalisation on past practices in not favourable (Byggenæringens-Landsforening, 2020).

Emerging trends are shaping the future of AEC/FM in Norway as well as internationally. Trends such as "lean processes" identified in the Norwegian Digital Roadmap 2.0 as "digitalised improvement processes" in construction projects (Byggenæringens-Landsforening, 2020), illustrate increasing industrialisation towards automation, the use of robotics as well as prioritising off-site construction. Indeed digitalisation is specifically referred to as industrialisation as the goal with digitisation is to ensure that "processes" and "systems" in place are well developed to meet the needs of stakeholders (Byggenæringens-Landsforening, 2020). Furthermore, these trends include life-cycle mapping, indicating a requirement for detailed information on buildings and infrastructure with digitalisation enabling and supporting lean processes and increased effectiveness (Byggenæringens-Landsforening, 2020). Within the document sustainability is referred to along with deconstruction and environment. There are links to resource efficiency as referred to earlier, but also indication that these concepts are open for the industry to understand making the sustainable aspects obscure. The same document raises the challenge of asset traceability as the future of the industry is one that requires lifecycle thinking and with it documentation of all the tasks and operations as well as all the materials and properties of our buildings (Byggenæringens-Landsforening, 2020). Documentation and traceability of asset information is viewed along with adaptability in buildings and circular economy within the sector implying how digitalisation can enable sustainable buildings. The document further refers to the need for achieving a higher level of digital maturity both among people and organisations within different disciplinary boundaries through better planning and preparation (Byggenæringens-Landsforening, 2020) There are different degrees of BIM and digital technologies used across different disciplines and organisations in Norway along with different systems in place which creates a complex picture in achieving the goals of digitalisation (Byggenæringens-Landsforening, 2020).

Individual vision documents, frameworks, roadmaps, and standards can create guidelines for digitalisation and sustainability targeted at the current and future industry outlooks. However, ultimately actors at the national level need to come together to produce joint frameworks. A joint framework can aid in developing better understandings that is currently lacking in information particularly when it comes to developing a common language among the industry stakeholders (Byggenæringens-Landsforening, 2020). This is important because the existence of multiple standards and frameworks within the industry hinders the digitalisation process (Byggenæringens-Landsforening, 2020). Similarly, to Norway, there are co-dependencies between digitalisation and sustainability demonstrated in key documents in the UK. The emergence of Artificial Intelligence (AI) emerges as influencing the processes in real estate and construction industry in automating tasks and processes with one such example in "real estate surveying" (RICS, 2020). In addition, there is reference to many potentials in the use of BIM-enabled AI for facility management particularly in space management and achieving sustainable goals. Sensor technology through data collection and in combination with AI can allow better performance of buildings as well as better maintenance measures and practices (RICS, 2020). The narrative of potentials indicates that this is not attainable today but is attainable someday with the view of automation building from the technical standpoint of what technology can offer in terms of performance but a vision of how and when these possibilities can be attained is unclear. Within this narrative an imagined future is being created for FM but is not fully mapped of how this can come to be. The documents from the UK and Norway examined in this review indicate a future based within a technological knowledge boundary, but the meaning of this in terms of the many disciplinary knowledge bases that makes up the building industry is not clear from the initial observations of this work. While knowledge boundaries between technology and sustainability appear to be crossed, the built environment disciplinary knowledge boundary appears to need further integration.

The digitalisation of the AEC/FM sector in framework documents

Based on the articles examined in this review, trends are moving toward automation and ways of reaching sustainable targets which is embedded in the frameworks. Frameworks are a tool to map different ways that the building industry can collaborate, but this is primarily on the technical level rather on a knowledge-based interaction level. Indeed in Norway, Digitalt Veikart 2.0 refers to the existence of standards and guidelines that are being developed by ISO and CEN which emphasise the importance of Norwegian frameworks as part of European and international market (Byggenæringens-Landsforening, 2020). It further emphasises that it is incumbent upon all those active within the field to clarify and distinguish which of the international guidance should be used in Norway. There is a need for "common services" to be established based on a terminology catalogue of definitions with a "rule-based vocabulary" (Byggenæringens-Landsforening, 2020). The document emphasises that the common components of a digital platform at national level should be based on how we digitalise together and should reflect the level of competency that is actual at any given time, meaning that it needs to be dynamic (Byggenæringens-Landsforening, 2020).

Framework documents in Norway such as Neste steg model (Next Stage Model) provide a general outlook of the industry. Neste steg presents eight core stages of a building project through a whole lifecycle approach. It emphasises the common principles and language within the industry in which correct delivery of information from one stage to next is seen as the goal (Bygg21, 2015). Importantly this model identifies who is responsible for what, at the same time it is limited by the phased approach where certain epistemic groups are present, and others are creating boundaries of knowledge within the phases but not across. Reuse of BIM in the operation phase is projected to lead to satisfied clients and use of real operational data that is projected and automatically generated can lead to sustainable buildings and reuse of materials (Byggenæringens-Landsforening, 2020). Frameworks appear to balance between industrialisation with a reliance on technical outcome and the execution of collaborative process, but these processes are still broken up by specific phase lasting a certain time and space and involving particular actors of that time and space. It is unclear if collaboration is contained within these phases by the actors alone with the digitalisation systems and processes viewed as continuity.

In the United Kingdom, the Centre for Digital Built Britain (CDBB) was created as a collaboration between the government, the Department for Business, Energy & Industrial Strategy (BEIS) and the University of Cambridge (CDBB, n.d.). The centre was active between 2017 and 2022 and took the initiative to advance digitalisation and information management in the UK infrastructure and AEC/FM industry with the purpose of digitalising the entire project lifecycle (CDBB, n.d.). The vision for the Digital Built Britain sees the four stages of Design, Build, Operate and Integrate as integral to the future of the built environment (Hetherington and West, 2020). Here Integrate is viewed as novel going beyond the traditional division of different practices of the building industry with the intentional integration position. Within this, Digital Built Britain presents a bottom-up approach to the workflow with regards to data and information management in which the data from several "isolated assets (Project BIM)" should pave the way for analysis and monitoring of data in a large portfolio of assets. Such a portfolio of assets in the next stage can form the basis of the larger unit which would be the regional or the "smart city" unit (RICS, 2020). This is expected to be the approach across all stages of the project from design to operation of buildings and basing decisions on the total expenditure cost (TOTEX), an approach that requires availability of data across the project lifecycle, reshaping the working methods of the otherwise traditional industry and project processes (RICS, 2020). The use of this framework within these four stages tangibly illustrates a collaborative effort which goes beyond technical processes.

Importantly in the UK, a BIM framework was also created in the past few years. Similarly, to Norway, the use of a framework containing standards, guidance, and information resources help implement BIM and information management across the AEC/FM industry. This framework has been developed by the organisations British Standards Institution (BSI), Centre for Digital Built Britain (CDBB) and UK BIM Alliance(BSI, 2019). The framework is again an explicit joint collaboration between government and industry and is based on the international standard ISO-19650. This a standard that is related to BIM and targeted towards "information management processes and technical solutions", it contains six stages of guidance form 0-5 (BSI, 2019).

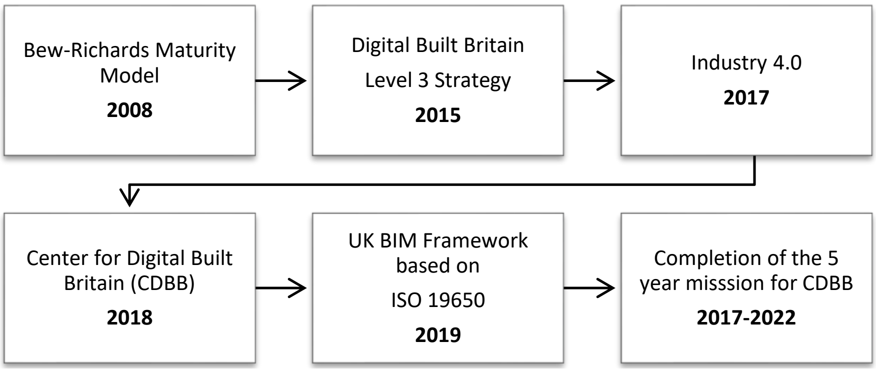

Figure 3 The stages of BIM definition and terminologies, and its associated technologies in the United Kingdom redrawn based on RICS (2020).

Stage 0 of the framework elaborates the case for information management in which the guidance first gives a context of the digitalisation and points out the "low productivity" of the construction sector globally (BSI, 2019). It then sets out the importance of information management, elaborates on the affected parties in information management and provides information about the benefits of information management and how the right quality of information can impact decision making (BSI, 2019). In stage 1 some of the concepts related to information management, digitalisation, and BIM as well as the goals of information management along with the existing opportunities are defined and explained both in general terms as well as with the understanding of the context of the industry in the UK (BSI, 2019). This is a collaborative framework that has an all-encompassing approach corresponding to the needs of the industry including buildings of all sizes and programmes (RICS, 2020). In this framework stages 2-5 consecutively provide guidance for: The "Delivery phase", "Operational Phase", "Information Exchange" and "Security-Minded approach to Digital Engineering" (BSI, 2019). This bottom-up approach further extends to efforts to have a National Digital Twin (NDT), where the digital twin is not one large Twin model but is based on a secure network of several digital twins at various scales (Hetherington and West, 2020). The NDT is mainly geared towards infrastructure professionals and is expected to help decision-making, information transfer, data integration and collaboration at different levels be it at the asset level or the larger system across the "natural and built environment"(Hetherington and West, 2020).

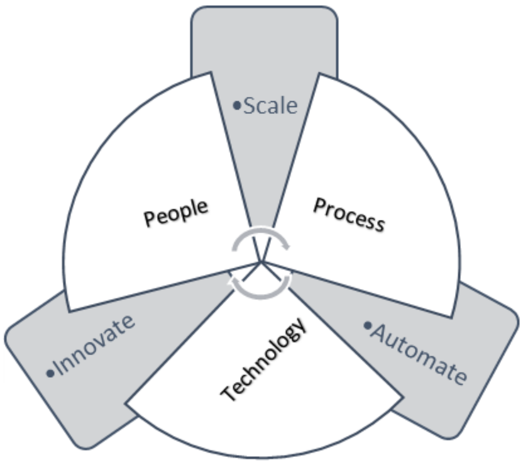

Figure 4 The elements needed for successful information management implementation redrawn based on UK BIM Framework Guidance (BSI, 2019).

Digitalisation in Norway is seen as key in the process of future shaping within the industry, as it is suggested that road maps and targets should focus on how the future could be shaped rather than what eventually could come with it (Byggallianse and Eiendom, 2016). In both the UK and Norway adhering to common standards such as ISO-19650 for taking BIM on board should provide clarification of information and definitions for "asset owners" and "clients" supporting building lifecycle processes. If the quality of the information is ensured and provided that information is enough and adequate about the project or the asset, it can then be used for better decision-making throughout the project lifecycle (BSI, 2019, Byggenæringens-Landsforening, 2020). Importantly for facility management, it would support the transition of information throughout the project lifecycle, binding the otherwise detached project stages together and crucially facilitating the information transfer between "project delivery and asset operation" (BSI, 2019).

CONCLUSIONS

Innovation process is defined by environment and context (Papdonikolaki et al., 2022). Context is seemingly often emphasised in the industrial frameworks and guidelines in the UK and Norway reviewed in this article, which can be limited by the current environment of what is possible. The frameworks and guidelines seem to over-emphasise the technology and the process while overlooking the collaboration of diverse actors. Communication amongst these actors has not been clearly seen within these documents, while Dossick and Neff (2011) have emphasized communication as necessary for adoption of these technologies. At the same time, the UK appear to become more explicit in their framework for collaboration in recent years through the fourth stage of 'integrate'. Whereas there is discussion for the need for collaboration in the strategy documents in Norway, the frameworks seem to limit this collaboration within phases in the building sector rather than across phases illustrated a type of bounded collaboration.

Imaginings (Ivory, 2013) seem to be extended into the operational sector within strategic frameworks, where there is a clear focus on the potential of this technology in both the UK and Norway. At the same time, these imaginings appear intangible occurring at some point in the future and when the future to be is not clear. Scenarios are often used in strategy making. Knowledge integration and scenarios will be further examined in the next step of this review of frameworks as well as taking in a larger number of framework and strategic documents for digitalisation in the UK and Norway.

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A Technology-Based Facility Management (FM) Approach: Addressing the Challenges of Future FM

Wills, N.[1] and Bartels, N.[2]

ABSTRACT

Background and aim – Facility management (FM) entails multidisciplinary technical, infrastructural, and commercial activities that ensure the functionality of the built environment by integrating people, places, and technologies. Despite emerging technologies such as the Internet of Things (IoT) or Building Information Modeling (BIM), the execution of FM services requires human labor. The current and future skills shortage poses challenges for FM in two ways: 1) carrying out necessary activities to ensure operator responsibility in a timely and appropriate manner; and 2) coordinating and arranging activities that increase customers' and employees' satisfaction. In this context, this paper provides a digital FM approach that makes FM more efficient by using the concept of gamification. Therefore, new technologies (NT) such as artificial intelligence, IoT, and BIM are analyzed to identify methods for enabling the efficient management of buildings while taking employees' needs into account.

Methods/Methodology – This research comprises an analysis of the challenges faced in the effective fulfillment of operative FM tasks: the skilled worker shortage, digital NT, and gamification. A systematic literature review forms the basis for developing a game-based concept. Moreover, motivating factors for employee satisfaction are identified and linked to NT using the concept of gamification.

Results – A conceptual approach is developed in which people, NT, and data are interrelated to ensure the fulfillment of facility services. This is the first draft, and it accounts for employee motivation in a game-based context.

Practical or social implications – This approach presents possible methods for counteracting the skills shortage in FM that is set to worsen in the future by acting early in the critical areas. The developed framework shows future actions that both researchers and organizations must consider in greater depth to ensure employee satisfaction and optimal service delivery in FM.

Type of paper – full viewpoint paper.

KEYWORDS

facility management, new technologies, skilled worker shortage, data-driven FM, gamification

INTRODUCTION

The management of buildings in facility management (FM) comprises many technical, infrastructural, and commercial activities that significantly contribute to companies' and organizations' ability to focus on their core business (Gondring & Wagner, 2018). FM encompasses all activities required to operate

[1] Department of Business and Engineering – Real Estate, Technische Hochschule Mittelhessen - University of Applied Sciences, Friedberg, Germany, Nadine.wills@wi.thm.de
[2] Faculty of Civil Engineering and Environmental Technology, TH Köln - University of Applied Sciences Cologne, Germany, niels.bartels@th-koeln.de

and maintain buildings, including property supply and disposal, cleaning and maintenance, and supporting processes in human resources, accounting, and purchasing (the German Facility Management Association [GEFMA], 2004). FM not being listed as an industry in its own right makes it difficult to quantify the services provided in the sector (Thomzik, 2022). However, its turnover is quantified through statistics: Between 2010 and 2020, the turnover increased from €44.7 billion to €54 billion, with 31.5 % of this revenue share being generated from providing technical FM services, 59 % from infrastructural FM, and 2.4 % from commercial FM (Lünendonk & Hossenfelder GmbH, 2021). Approximately 5.03 million employees created this revenue (Thomzik, 2022).

In the context of digitization, new technologies (NT) are being used in FM, with Big Data, sensor technologies, artificial intelligence (AI), and Building Information Modelling (BIM) being the main focus (Demirdöğen et al., 2023). Using NT in FM does not imply that labor can be completely dispensed with, especially in terms of operations, as Piazolo et al. (2021) stated that only approximately 47% of work processes in the real estate sector can be digitized, such as through robotics (e.g., using cleaning robots in infrastructural FM or drones for maintenance in technical FM). However, the shortage of skilled workers in FM is already apparent and will intensify further. Accordingly, until 2025, companies that provide FM services must fill 75% of their open positions (Lünendonk & Hossenfelder GmbH, 2020b). This shortage of skilled workers is due to several factors: one set of restrictions includes demographic developments, global changes, lack of attractiveness of training, and technological advances and digitization The second set comprises soft factors such as low salaries, lousy working conditions, missing qualifications, or fluctuations in the number of skilled workers due to employee dissatisfaction (Ahlers & Quispe Villalobos, 2022). While employing NT to address the worsening shortage of skilled workers seems sensible and logical, the effects this has on employed skilled workers should be considered, with job loss being a major consideration due to the demotivating effects it has. Completing FM tasks to ensure building operations even though there is a shortage of skilled workers, the implementation of new technologies has to be addressed. Gamification is a potential solution for addressing the skilled worker shortage in FM activities that cannot be automated. Gamification relies on motivation research and uses game elements in non-game environments, such as professional settings (Ellenberger et al., 2020). Therefore, this paper aims to develop a concept that evaluates the proposed solution of using BIM, sensor technologies, Big Data, and AI to address the labor shortage, with gamification being incorporated into the framework (see Figure 1). The investigation is limited to employee turnover based on demotivation and dissatisfaction.

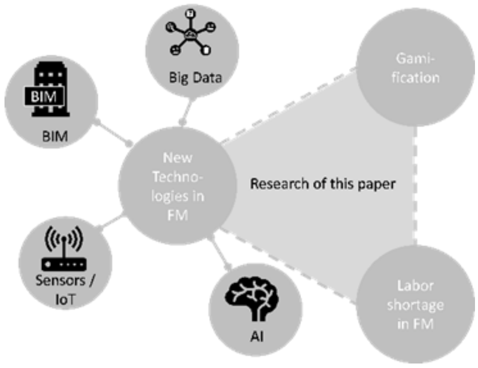

Figure 1 Research goal.

The results of a systematic literature review conducted by the authors between 2018 and 2023 before the preparation of this paper were used as the baseline for identifying the emerging technologies in FM. Since this paper's focus is not on the literature review but on the development of a concept to increase employee motivation using gamification, the procedure of the literature review is only briefly explained, with the findings being directly related to the results. NT and motivation factors are considered together to identify methods for making working conditions more attractive. The goal of this paper is not to replace operational tasks with NT, such as robotics, but to identify strategies for making working conditions more attractive through the use of NT. The result is a draft concept that represents the possibility of using NT and gamification to provide technical FM services (i.e., maintenance, repair, and ad-hoc services) that meet legal requirements against the backdrop of the skilled worker shortage. The objective is to motivate employees in a way that precludes employee turnover. The paper concludes with a discussion of the results and an overview of potential future research directions.

RESEARCH METHODOLOGY

In the first step (Input), the reasons for the skilled worker shortage in FM are discussed, and relevant NT in FM that could avoid this shortage through encouraging employee motivation are identified by conducting a literature review. Using this information, a concept is developed that uses motivating factors for fulfilling technical FM tasks as a basis and links them to NTs by considering gamification. As has already been demonstrated, there is a correlation between the motivation of individuals (in this case, employees) and the efficiency of performance (Schwalbach, 1998). The use of incentives serves to activate motivation. Motivation is determined by the expectation of the employees regarding the reward of the performance to be achieved. In this paper, however, the focus of reward is not on monetary aspects but on psychological aspects that help increase employees' well-being. Gamification offers the possibility to realize the use of new technologies and the definition of incentives to increase motivation. The process of concept development is divided into two steps: In the first step, employees' physical and psychological motivating factors are analyzed, which is then followed by an overview of how gamification serves to link NT and motivating factors. This results in the identification of a framework that includes the relevant NT to address the skilled labor shortage in FM.

LITERATURE REVIEW

FM Service Provision

FM encompasses various technical, infrastructural, and commercial services that are required for managing buildings. Various institutions, such as the GEFMA and the German Institute for Standardization (DIN), provide a general overview of the required services. The volume of services required depends on the use and size of the building and the number of systems therein. Determining FM's multidisciplinary range of activities, the heterogeneity of buildings, and the types of use is a complex process. In addition to ensuring plant availability, the required activities include adherence to legal regulations to ensure the safety of building users, such as operator responsibility (GEFMA, 2004). Failure to comply with legal and plant-related requirements poses a risk to building users in the event of damage and may result in criminal prosecution. Accordingly, timely and effective service delivery is a top priority for FM service providers and their workforces. There are different strategies for maintaining and building service equipment: condition-based, predictive, and reactive (DIN, 2019). The work packages, including the tasks required to be performed by specialists, are compiled based on the strategies applied. In addition to regular and planned activities, unplanned (ad-hoc) services are also provided. For example, ad-hoc failures of systems that have high criticality require service provision at short notice. Ad-hoc tasks in particular require a high degree of flexibility from specialists as well as the ability to prioritize activities independently in the shortest possible time. Using asset prioritization that is based on criticality supports the prioritization of the required activities (Stolzenburg, 2017). Nevertheless, tasks resulting from ad-hoc equipment failure lead to delays and shifts in employee activities. At the operational level, it is usually the employees' decision of which activity should be quickly carried out on which system. In order to complete the unscheduled activities resulting from plant faults (at critical plants) as quickly as possible, employees take detours. This leads to both delays in the planned daily schedule and additional physical stress. Moreover, if planned activities cannot be carried out, there is also the risk of excessive demands and demotivation (Rheinberg & Engeser, 2018).

Skilled Worker Shortage and Employee Satisfaction

A survey conducted in Germany in 2022 among clients (n=60), facility service companies (n=20), and consulting firms (n=19) revealed that FM-specific causes of staff shortages among service providers include poor pay (64%), a poor image of the industry (40%), migration to better-paying jobs (22%), unwillingness to undergo training (19%), insufficient attention to tasks (16%), excessive overtime or working hours (15%), and high workloads (10%) (Lünendonk & Hossenfelder GmbH, 2020b). While poor pay is companies' internal problem, using NT can positively affect the other causes of skill shortages. Given the skilled worker shortage in operational FM, a demand-oriented and resource-saving execution of activities proves to be complicated. Due to demographic changes and the imminent retirement of the baby boomers (i.e., those between 60 and 79 years), the shortage of skilled workers will worsen. FM companies in Austria, Germany, and Switzerland consider solving the skilled worker shortage an overriding strategic goal, with the recruitment of new specialists and the retention of those already in these companies dominating the topic (Lünendonk & Hossenfelder GmbH, 2022; Statistisches Bundesamt [Destatis], 2023).

To ensure the proper performance of operational FM activities despite this shortage of skilled workers and to avoid worsening the staff shortage through additional employee turnover caused by dissatisfaction, employee satisfaction must be considered. In the service sector, which FM belongs to, employees are a central resource. Despite the importance attached to the performance of employees' tasks, many service employees need to be better qualified (or qualified at all), and they must be encouraged to work in a customer-oriented manner, thus increasing their motivation to do so. In many service industries, employees with direct customer contact are employed as temporary workers and paid the lowest rates. This results in poor service, which is followed by a slide into mediocrity. For an FM service provider, willing and able employees represent a considerable competitive advantage if employee satisfaction is developed and maintained in a targeted and competent manner (Haller & Wissing, 2022). Employee satisfaction depends on companies' intrinsic factors: job design, personnel selection and development, employee compensation and recognition, job type, and performance tools (Heskett et al., 1994).

NT in FM

To identify the scientific and practical uses of NT in FM, the authors conducted a systematic literature review before completing this paper. Harzing's Publish or Perish software was used to retrieve and analyze academic citations from various external and scientific data sources (Adams, 2016): Crossref, Google Scholar, Google Scholar Profiles, PubMed, Scopus, and Web of Sciences. The keywords employed included "new technologies in FM," "technology-based FM," "digitalization in FM," "FM and new technologies," "technology-oriented FM," and "digiFM." A strong connection was found between the "facility management" and "new technologies" search terms in the literature. Furthermore, "Big Data," "sensor technologies," "AI," and "BIM" were the most frequently mentioned terms in the search query, which is why these aspects were identified as the focus herein.

Big Data primarily denotes the processing of large, complex, and rapidly changing amounts of data, and it is thought to expand the boundary of data science because innovation is ongoing to promote the ever-increasing capacity to collect and analyze the high volume, velocity, and variety of data available (Tractenberg & Sellers, 2017). A data-driven FM approach describes the intelligent operation of buildings and processes based on available building-relevant data (Lünendonk & Hossenfelder GmbH, 2020a). Software systems for offering and storing FM-relevant data include computer-aided FM (CAFM) systems or building management systems (Bartels, 2020). Using sensor technologies in FM generates extensive data that can be used in Big Data approaches. The Internet of Things (IoT) and sensor technologies provide data to describe the current behavior of objects and people (Vornholz, 2019). Classic applications of sensor technologies and IoT in FM include energy monitoring, indoor climate conditions, disaster management (Jeon et al., 2018; Sun et al., 2021), space management (Lünendonk & Hossenfelder GmbH, 2020a), and cleaning management (Ballard, 2021). Using demand-oriented, anticipatory service provision in which activities are only carried out when needed can increase efficiency by reducing the distances traveled by skilled workers (Wills, 2023).

AI technologies are methods and procedures that enable technical systems to perceive their environment, process what they perceive, solve problems independently, make decisions, and act and learn from these decisions and actions (Enholm et al., 2022). In doing so, AI does not develop human capabilities: It performs specialized tasks by using its high computational capacities to process volumes of data that humans could not possibly process in an equal amount of time (Janiesch et al., 2021). In FM, AI methods are used to save energy within the sustainable management framework in particular (Lee et al., 2020; Villa et al., 2022).

The literature and practical use have proven that BIM supports efficient FM processes as it enables the storage, use, and integration of data and information for the phase of building use. In terms of the entire building life cycle, implementing BIM in FM can lead to an increase in the value of the building by coordinating processes of information exchange between the construction and occupancy phases, facilitating the correctness and availability of FM data, and increasing efficient work order execution (Pärn et al., 2016). Using BIM in FM is possible in various fields, such as space management (e.g., occupancy planning), lease management (e.g., transfer of tenant data or user data into the BIM model), or maintenance and repair (e.g., graphically supported navigation through the building and its facilities; (Hu et al., 2018). Each of the above technologies provides opportunities and challenges for FM, as presented in Table 1. As digitalization and automation are factors that lead to success in the real estate sector, the use of NT leads to new possibilities when meeting FM service provision requirements (Piazolo & Dogan, 2021). However, digitalization and automation in the real estate sector focus on building system technology, building control technology, and processes of commercial FM, such as calculation, cost, performance accounting, and object management, while maintenance management, building services, and FM coordination cannot be automated (Piazolo & Dogan, 2021).

Table 1: The opportunities and challenges in integrating NT into FM

Technology	Scope of application in FM	Opportunities	Challenges
Big Data	Predictive strategies	Increase in efficient building maintenance, including energy savings and optimization of processes	Choosing the correct data; data analysis
Sensor technologies	Energy monitoring; indoor climate conditions; disaster management; space management; cleaning management; demand-oriented service provision	Increase in efficiency by reducing the distance traveled by skilled workers; saving time by automating the information provided on required maintenance and inspection periods	Additional costs for physical sensor technologies; extra work in terms of maintaining the sensor technologies; skilled workers required
AI	Energy savings; sustainable FM; predictive maintenance	Prediction of faults; prevention of breakdowns by decision engines; smart choices are made (even by unskilled employees)	Large amounts of data required (e.g., for training the algorithm)

BIM	Space management; lease management; simulations; sustainability	Providing the information required to complete FM tasks; visualization of elements and spaces relevant to FM	Early inclusion of FM to obtain the information required for building management; loss of information between the planning and use phases

Gamification in FM

For FM activities that cannot be automated, motivational processes and tools are needed to address the skilled worker shortage. Gamification is one such solution. This comprises using game elements in non-game environments, such as those of a professional nature (Ellenberger et al., 2020). Gamification relies on motivation research, which is significantly correlated with the self-determination theory, with the validity of the research on the motivational effect of gamification being confirmed in various studies. The self-determination theory states that motivated actions can be differentiated according to the degree of self-determination, which is the "extent to which a motivated action is experienced as freely chosen." If actions correspond to an individual's goals, they are perceived by the individual as being freely chosen, that is, self-determined (Deci & Ryan, 1993, p. 225). The self-determination theory also distinguishes between intrinsic and extrinsic motivation. Intrinsic motivation is "why individuals strive, free from external pressures and internal constraints, for an activity in which they can be committed to doing what interests them" (Deci & Ryan, 1993, p. 226). Therefore, the motivation arises from the activity. Extrinsic motivation is when an external impulse occurs, which implies the need for specific behaviors and is associated with rewards or punishment (Stöcklin, 2018). Thus, intrinsically motivated behavior is associated with a high degree of self-determination (Deci & Ryan, 1993). The literature details various approaches to applying gamification in the literature (Sailer, 2016). The Octalysis framework is one such approach as it offers numerous starting points for selecting and combining suitable game design elements (Chou, 2016). The framework is based on eight Core Drives that have an intrinsic, extrinsic, or hybrid motivating effect:

- Epic meaning and calling (hybrid): The user believes that they are part of something bigger.
- Development and accomplishment (extrinsic): Users' motivation is driven by achieving progress.
- Empowerment of creativity and feedback (intrinsic): Users are engaged in creativity processes and receiving feedback.
- Ownership and possession (extrinsic): By having ownership over something, users' desire to improve the thing they own increases.
- Social influence and relatedness (intrinsic): This comprises the kinds of social interaction (e.g., mentorship or competition) that motivate users.
- Scarcity and impatience (extrinsic): By suggesting exclusivity, through the implementation of waiting periods for example, users are bound to play again later.
- Unpredictability and curiosity (intrinsic): Unpredictability is the core driver of users' constant engagement due to the uncertainty of what will happen next.
- Loss and avoidance (hybrid): This entails preventing negative events from occurring (Chou, 2016; Huotari & Hamari, 2012).

Using gamification in FM has already been described in the literature, with a particular focus on achieving sustainability goals (Bantle et al., 2022), building users saving energy (Berger et al., 2014), monitoring building information (Kán et al., 2021), and training employees in the facility services sector (Fager et al., 2018).

RESULTS

Concept Development

Based on the literature review, this section presents a concept for integrating gamification aspects that are based on NT into FM to solve the skilled worker shortage. The focus of this model entails increasing employee satisfaction through the use of NT, which will stop employees from leaving the sector (see Figure 2).

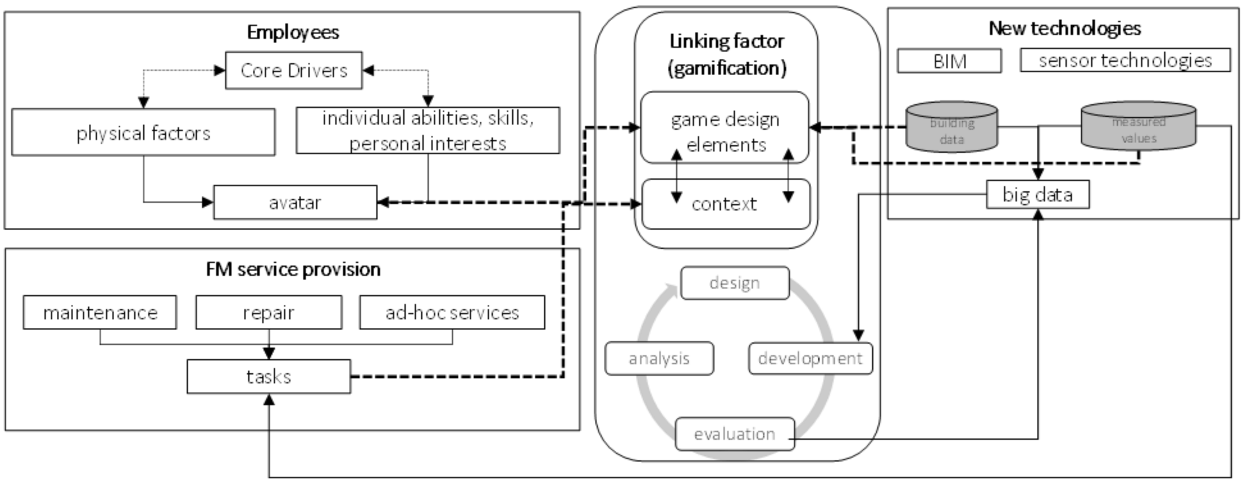

Figure 2 Framework for using NT in FM to address the skilled worker shortage.

Step 1: Identifying physical and psychological motivating factors for a gamification concept

While identifying motivating factors for employees, Heskett et al. (1994) detailed the importance of employee satisfaction for customer satisfaction and loyalty and, thus, profitability through the service-profit chain. As discussed above, internal service quality consists of intrinsic factors that increase motivation. Herein, intrinsic factors related to NT include job design and performance tools. According to Rheinberg (2010), the motivation to engage in an activity lies in the activity incentive and the follow-up incentives thereof. In technical FM, the following activities are considered: maintenance, repair, and ad-hoc equipment failures. Due to legal regulations and plant-specific manufacturer specifications, activity incentives for maintenance and repairs offer little scope for action. The motivations for engaging in activities are divided into psychological and physical motivating factors. The psychological motivating factors are intrinsic and include employees' abilities, skills, and interests, which result from the actual occupational field. For example, an electrician or electrical engineer has an interest and know-how in the electrical engineering trade, and a plumber has expertise in the specialist area of plumbing. The physical motivating factors comprise external aspects that are related to employees' bodies, and they include physical characteristics such as age, weight, height, limitations, or pre-existing conditions. Identifying employees' physical health and body parameters allows for the determination of their employment possibilities in the trade in which they work, and it also allows for the identification of specific facilities they should service. Table 2 details the relationship between the motivating factors and their incentives.

Table 2 Motivating factors and their incentives.

	Psychological motivating factors	Physical motivating factors
Activity incentives	Individual abilities; skills; personal interests	Physical factors: age, weight, pre-existing illnesses, limitations
Follow-up incentives	Positive self-assessment of personal skills (increase in competence, sense of achievement, pride, and joy in personal ability); enjoyment of a perfect, harmonious movement; self-forgetfulness (switching off, being absorbed in the activity, forgetting, excitement and thrill); connection, community, and sociability (Rheinberg, 2010)	Positive feelings about one's body during the performance of tasks, with personal physical needs and preferences being accounted for

In order to align the psychological and physical motivational factors with the gamification-based approach, the factors shown in Table 3 are categorized into the Core Drives. For employees to achieve the follow-up incentives, different forms of motivation can be used, whether intrinsic (e.g., trophies, research points, or bars) or extrinsic (e.g. team missions).

Step 2: Identification of motivating factors and linking them to NT

After identifying the motivating factors for employees, they must be meaningfully related to NT, which is the area in which gamification plays a central role. In this context, an avatar is created, which is a representation of a skilled worker who is solving different tasks in a game context. The motivating factors for creating an avatar can include physical factors, individual abilities, skills, and personal interests. Moreover, FM service provision, which consists of maintenance, repair, and ad-hoc services, is also integrated into the game setting. After integrating the employees into the gamified concept, NT are then implemented, with BIM, sensor technologies, and AI defining the game in the first step. Building information models entails creating virtual representations of the built environment that are used in the game's design: The building information models contain the assets and elements within the buildings as well as the information required for providing services at the facilities. The data generated by sensor technologies deliver information according to the facilities and the employee's location within the building. After this, additional NT, comprising AI and Big Data, are used to create tasks based on the actual service delivery needs according to the data generated by the sensors. Following this, AI prioritizes the tasks according to their importance, with ad-hoc services also being considered. Based on the employee's location data, the AI then generates the best sequence of activities and the optimal routes for the employee to take to process the work packages, which will be displayed on the employee's smart device, such as a smartphone or tablet. Thus, the execution of the tasks is detailed for the employee through visual support according to the routes and required information on the facilities and activities that are stored in the BIM models. Figure 3 delineates the process of using NT as game design elements.

For each completed task, the employee receives incentitives (e.g. a trophy), which increases the motivation. These rewards are credited to the employee's account and can be used for fair work performance evaluations. In addition to individual tasks, the AI can also consider team tasks for activities that require several employees. The execution of activities to achieve awards, which motivate employees (as they gain benefits such as fair evaluations or salary increases), can be used specifically to manage operator responsibility. Activities required for legal compliance can be implemented explicitly in the setting.

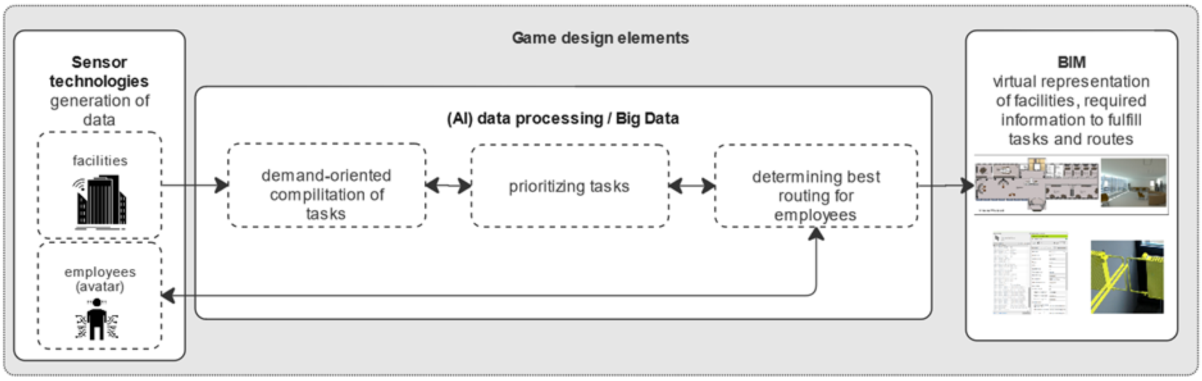

Figure 3 NT as game design elements

DISCUSSION AND CONCLUSIONS

As literature and practice have proven, the current skilled worker shortage will continue to worsen. Digitization and NT can currently be used to continue the provision of required services during the skilled worker shortage, but they are restricted to automating operational tasks in FM. To prevent employees from leaving companies due to dissatisfaction, which intensifies the effects of a demographic shortage of skilled workers, motivational factors must be considered in order to both establish employee loyalty to the company as well as perform FM activities in a legal manner without employees being under- or over-challenged. A combination of BIM, sensor technologies, and AI as game design elements in the gamification of FM service provision can be used to support this provision in various ways: Data generated by sensor technologies can use algorithms integrated with AI to logically sequence activities and take into account ad-hoc activities. In this way, skilled workers can save on the distances they travel, leading to an increase in efficiency, and BIM allows workers to receive the relevant information about activities needed to retrieve the assets required for an order. Furthermore, using different forms of motivation while fulfilling FM tasks, such as progress bars or trophies, supports employees psychologically. The Core Drives of the Octalysis framework are integrated into the developed approach through ad-hoc services (unpredictability and curiosity) or in the use of the achieved motivational factors to receive feedback in the form of fair employee evaluations (development and accomplishment). A framework that focuses on employee satisfaction while simplifying tasks in a game-based environment using BIM, sensor technologies, and AI could potentially offer an effective solution. Furthermore, it could also be used to encourage employees to participate in further training by, for example, requiring employees to earn a certain amount of trophies before they can complete specific tasks. Thus, if the tasks are intrinsically motivating for the employee because they are interested in the task area, for example, they will be incentivized to reach the next level in the game.

Nevertheless, this study has several limitations. Firstly, the concept developed herein is a first draft that needs to be practically tested. Moreover, additional NT, such as blockchain and AR, were not considered herein, which can be investigated in future research. Additionally, interfaces between the individual NT were not considered in the framework. Therefore, when practically implementing the system, the interoperability of the systems must be ensured. In further investigations, greater attention must be paid to the issue of data protection as, in this first draft, the avatars created had minimal data protection.

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In the context of digital transformation: an analysis of future requirements for the FM labour market

Bartels, N.[1] & Wills, N.[2]

ABSTRACT

Background and aim – The multidisciplinary spectrum of Facility Management (FM) activities requires employees to fulfill tasks. Moreover, new digital technologies, such as the Internet of Things (IoT), sensor technologies, the Building Information Modeling (BIM) method, virtual and augmented reality, or robotics, represent the possibility of work facilitation and change the way of delivering FM services. Therefore, practice as well as research and teaching must adapt to changing conditions. This research focuses on changing traditional operative FM services with regard to the digital transformation, mainly conducted by employees.

Methods / Methodology – First, an analysis of the status quo of traditional fields of operative FM services and current digital innovations is conducted. Next, a study of current job descriptions in FM is conducted to identify the demand for practice. Moreover, identified demands of practice are juxtaposed against the courses of studies and apprenticeships.

Results – The result is a matrix that guides universities and training companies for identifying the demand on required qualifications. The juxtaposition aims to highlight the required skills of future employees to fulfill FM services in the context of digital transformation.

Practical or social implications – The approach presents the change from manual doing in times of digital transformation change within the field of FM tasks. The change of fulfilling tasks also affects the future working environment.

Type of paper – Full research paper.

KEYWORDS

Digital transformation, FM services, demand identification, skilled FM workers, FM labor market.

INTRODUCTION

Facility Management (FM), as a lifecycle-orientated management discipline, needs and produces various data throughout the lifecycle of a building (Bartels, 2020). Digitization and data usage is mainly driven by the integration of various services in combination with the enlargement of the areas of interest, the complexity of relations between FM service functions, the service provider, and the customer, as well as the demand for efficiency and more sustainable service provisioning (Atkin & Brooks, 2021; Talamo & Bonanomi, 2016).

[1] Faculty of Civil Engineering and Environmental Technology, TH Köln - University of Applied Sciences Cologne, Germany, niels.bartels@th-koeln.de
[2] Department of Business and Engineering – Real Estate, Technische Hochschule Mittelhessen University of Applied Sciences, Friedberg, Germany

Especially in the Internet of Things (IoT) field, new tools can support the provision of FM services (Atta, 2021). The connection between IoT sensors (e.g., humidity, temperature, or presence sensors), the Building Automation System (BAS), and Building Information Modeling (BIM) offers new data to the FM to provide services more efficiently (Bartels & Weilandt, 2020). Various research in this field aims to

1. optimize user comfort based on IoT data (Laftchiev & Nikovski, 2016; Tomat, Ramallo-González, & Skarmeta Gómez, 2020),
2. improve the service provisioning, e.g., cleaning service by using a demand-orientated approach (Dahanayake & Sumanarathna, 2022; Wills & Bartels, 2022),
3. minimize energy consumption and improve sustainable O&M (Opoku & Lee, 2022; Serra, Pubill, Antonopoulos, & Verikoukis, 2014; Shah, Nasir, Fayaz, Lajis, & Shah, 2019) or
4. enable data-driven machine-based and deep learning for predictive maintenance (Bouabdallaoui, Lafhaj, Yim, Ducoulombier, & Bennadji, 2021; Cheng, Chen, Chen, & Wang, 2020; Sanzana, Maul, Wong, Abdulrazic, & Yip, 2022).

Besides that research, various Proof of Concepts (PoC) have been implemented (May, 2018). However, data and IoT tools are rarely used in FM. There might be various reasons, as

1. the data of the digital building model is not used throughout the whole lifecycle, as the FM is not seen as part of the BIM method,
2. various data formats are used during the lifecycle, such as Industry Foundation Classes (IFC), Construction-Operations Building information exchange (COBie), ProjectHaystack, or BrickSchema, which leads to data losses and inefficiencies (Wills & Bartels, 2022) and
3. the FM staff cannot conduct data-driven FM because of the IT skills, knowledge, and education (Mannino, Dejaco, & Re Cecconi, 2021).

Especially this third aspect is essential for the transformation of FM, latestly since new concepts such as Smart Buildings are gaining in importance. To fulfill all customer needs in the future, the FM must become the owner and critical user of the building data. With this, new jobs in FM might arise, such as Facility Data Manager or Smart Building Manager, that will be used as examples for new IT skilled job perspectives in this paper. Nevertheless, the Facility Managers, who are providing FM services, also need to deal with data, which means that IT and IoT skills rise in importance.

This paper evaluates how digitization in FM is seen in practice and in education. Furthermore, it wants to provide suggestions for further directions of digitization in Facility Management.

RESEARCH METHODOLOGY

The methodology of this paper consists of four steps, as shown in Figure 1. Step 1 is a literature review of existing IT tools that are used in FM and an outlook on how Smart Buildings will change the service provisioning of FM. This literature review forms the basis for the following analysis in the Steps 2 to 4. In Step 2, an analysis of requirements for FM employees occurs. Therefore, a meta-study of job advertisements in the German FM market was conducted. In Step 3, the results of this study form the basis for a survey among students to understand, what digital skills are expected by the students for future jobs in FM. The last step, Step 4, discusses the results of Step 2 and Step 3 in 4 workshops.

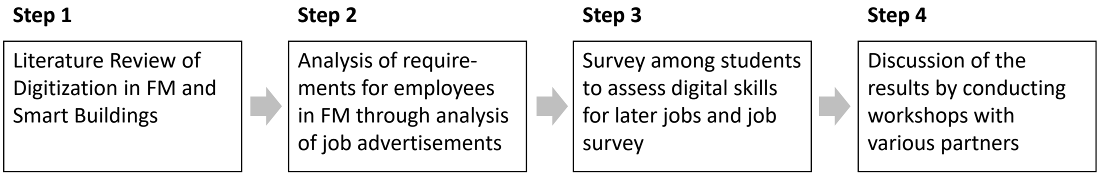

Figure 1 Research Methodology of this paper.

The chosen research methodology enables a discussion of both point of view – the employers' perspective as well as the student's perspective as future employees.

STEP 1: LITERATURE STUDY

FM currently faces a variety of challenges concerning digitization. The increased use of artificial intelligence (AI), robotics, and digital software tools is significantly changing the FM industry. Therefore, it is necessary to implement not only digital education but also digital job skills. Digital education in FM focuses mainly on using various software systems, e.g., Computer Aided Facility Management (CAFM), Enterprise Resource Planning (ERP), or Building Information Modeling (BIM). The following section shows the main digital influences on FM and the change caused by implementing digital tools in FM. Afterward, the education of BIM and the implementation of digital tools in practice are evaluated by conducting a literature review.

Software in Facility Management – Status Quo

Various software systems are used in FM to process dynamic and static data. Static data is data that changes rarely, such as the address of a building, floor plans, or further construction data (GEFMA, 2021). This data is generated by using the BIM method and is transferred to FM after the planning and construction phase of a building by using an as-built model (Bartels, 2020). In the operation and maintenance phase (O&M phase) of a building, many dynamic data is generated. Dynamic data changes rapidly, such as sensor data, data of service provision or customer requirements (Otto & Bartels, 2018). Combining that dynamic data with the as-built model is described as the as-operated model (Albert et al., 2021) calls evolution and is shown in Figure 2.

Various software systems exist for storing and handling these data. In the O&M phase, mainly the following software systems are used:

- CAFM systems support the service provision of Facility Management, such as cleaning, maintenance, repair requirements, and process information. Therefore a CAFM system stores, analyses, and displays alphanumerical (e.g. cleaning interval) and graphical representations of the building (e.g., floor plans) in a software system (Rudl, 2021).
- ERP systems are IT tools supporting the financial applications (Huang, Chiu, Chao, & Arniati, 2019). In FM, they are mainly used for Billing of services or contract management
- Computerized Maintenance Management System (CMMS) are used to store and analyse all relevant data of the building maintenance in one database (Condotta & Scanagatta, 2023).

- Building Management Systems (BMS): In BMS, the relevant data of the Building Automation and sensors are measured (Jandačka, Hrabovský, Kolková, & Florková, 2020).
- Integrated Workplace Management System (IWMS): IWMS is a technology that measures and analyses various IoT data to optimise built assets, fixed assets, mobile assets, and people (Maslesa & Jensen, 2019).

As can be seen in Figure 2, the amount of data of a building increase during the lifecycle, and in addition to that, the amount of software used increases, too.

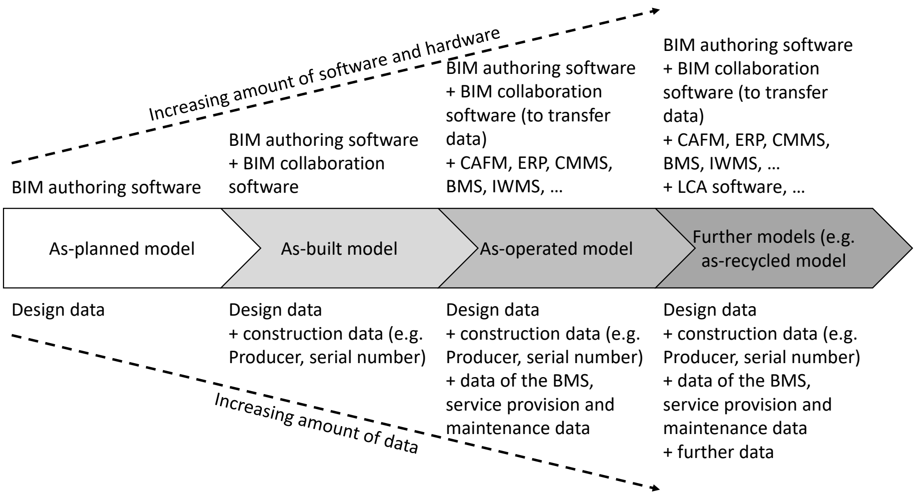

Figure 2 Evolution of data throughout the lifecycle (own representation).

These software systems interact in various ways, and the following Figure 3 shows an overview of some FM software systems. The connection between the CAFM system and the BIM method is described on the left side. To transfer data from the BIM software systems to CAFM, the Industry Foundation Classes Format and the COBie format could be used. The IFC format is a vendor-neutral and open standard that aims to exchange building data throughout the whole lifecycle of a building (Borrmann, König, Koch, & Beetz, 2021). The COBie format bases on IFC and aims to define the handover information required for Facility Management (East, 2013). The exchange of data between the design and construction phase (BIM software tools) and the O&M phase (CAFM system) can be done with IFC or COBie.

On the right side of Figure 3 is a CAFM-centric software system for FM. The CAFM system consists of functionality (coding), customizing, and dynamic and static CAFM data. Other FM software systems, such as ERP, DMS, or CMMS, are combined with the CAFM system.

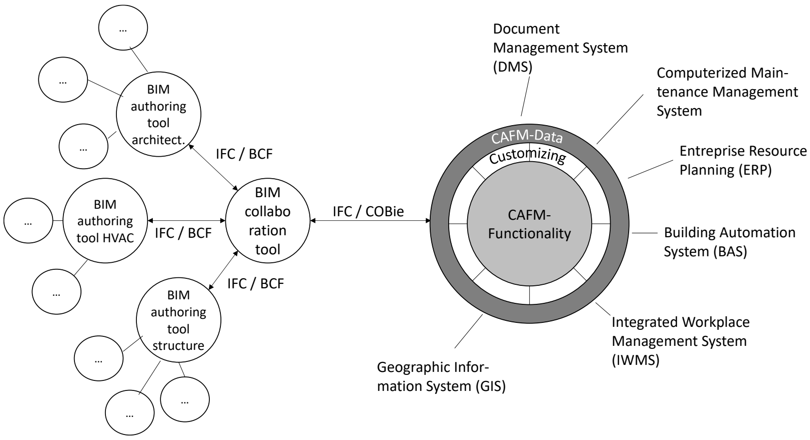

Figure 3 Software in Facility Management (own representation).

Besides the CAFM-centric software system, the ERP-centric software system is standard. While using CAFM-centric software systems for the provision of infrastructural and technical services, ERP-centric systems are chosen for providing economic services.

Smart Building and Facility Management

Besides the software systems mentioned above, FM uses various IoT Data. Especially modern buildings are planned and designed with various sensors that support the BAS or other use cases. Various software systems and sensors are the basis for the implementation and successful O&M of Smart Buildings. Especially in Smart Buildings, many sensors and IoT devices are installed to support an optimized lifecycle of buildings.

There needs to be a clear definition of a Smart Building (Araszkiewicz, 2017). However, it can be stated that a Smart Building relies on smart technology, such as IoT sensors, the digital building model created with the help of the BIM method and IT cloud structures as well as a user interface, such as mobile applications or desktop applications (Bartels & Weilandt, 2020). In addition to that, system, data integration, and IT integration, can provide more control and greater effectiveness in user communications (Buckman, Mayfield, & B.M. Beck, 2014).

While IoT and sensors and the use of the BIM method increase due to the implementation of Smart Buildings, the service provisioning of FM will be changed in the future. That means that Facility Management and current use cases must provide new use cases that will be adopted.

One major use case of Smart Buildings will be the balancing and monitoring of energy in buildings based on the building occupation (Chen, Cai, Li, Zhang, & Liu, 2022; Durand, Aguilar, & R-Moreno, 2022; Martani, Lee, Robinson, Britter, & Ratti, 2012). Table 1 shows the new critical skills for FM due to implementing IoT and Smart Buildings based on use cases.

Table 1 Exemplary Use Cases and necessary digital skills for FM, here: balancing and monitoring of energy in buildings (own representation based on (Altohami, Haron, Ales, & Law, 2021; Bartels & Weilandt, 2020)).

Use Case	Description	Necessary skills
Space Utilization Ratio	It will be necessary for FM to analyze the actual occupancy of buildings per day, week, and year to make suggestions to the tenant or owner as to whether space can be leased, e.g., through desk sharing or whether more space is required.	Data Analysis, Building Information Modeling, IoT and sensor data
Energy consumption based on occupancy	FM needs to combine data of the Energy Consumption in a defined period (e.g., minute or hour) and align these data with the occupancy in the spaces. If occupancy is missing, the energy consumption for heating or cooling can be reduced.	Smart Metering, Occupancy Analysis, Building Automation System, IoT and sensor data
Adaption of the service provisioning	The service provisioning consumes energy, e.g., for cleaning machines or water for cleaning. If spaces are out of use, this energy consumption can be reduced based on demand-based cleaning	Building Information Modeling, IoT and sensors, application
Using data for the design of new buildings	FM knows about the operated buildings. To design new buildings in order with sustainable goals, the FM will consult the designers and owners of future buildings	Building Information Modeling, data analysis, VR and AR for visualisation

As can be seen in Table 1, there is a high need for IT skills in FM for this use case. In addition to balancing and monitoring energy in buildings, other use cases are implemented in Smart Buildings.

Facility Data Manager and Smart Building Manager

Not only in Smart Buildings but also in various other service provisioning, IT skills will become more critical for FM. Furthermore, the FM has to change the way of service provisioning. Based on the literature review, a further direction could be to implement new FM jobs to fulfil the IT needs and skills that arise from IoT, BIM, and Smart Buildings in the future:

- Facility Data Manager (FDM): This job will handle all data that is created during the lifecycle of a building. The Facility Data Manager operates the IT cloud structures for FM, creates data analysis, and provides these analyses to the customer and the Facility Manager. The FDM needs skills in data analysis, IoT systems, IT cloud structures, and Building Information Modeling.
- Smart Building Manager (SBM): This job will operate and maintain Smart Buildings, which means that the manager is responsible for the FM service provisioning, the maintenance of IoT sensors, and the data maintenance of the as-operated building model. The information will be provided by FDM, who provides the IT cloud structures. He will also be the first contact person if applications need to be fixed as they should and forwards requests that cannot be solved to the application developers. The SBM needs to have skills in data analysis, IoT systems, and Building Information Modeling.

However, the skills must exist at the FM companies to implement such new FM jobs. Therefore, the required IT skills were analyzed as step 2 of the research methodology. The following section shows the results of Step 2, the meta-study of job advertisements. This section aims to get to know what kind of digital skills are relevant for employers.

STEP 2: EVALUATION OF REQUESTED IT-SKILLS IN FACILITY MANAGEMENT

Data Basis

In order to find out the requirements for IT skills for the FM industry 1,526 job advertisements were analyzed between 10.01.2023 and 08.02.2023. These were job advertisements from 1,408 companies. Of these, 311 job postings (from 298 companies) were in the construction management field to provide a comparison group. The job advertisements were taken from the most used German job advertisement websites for Engineering and Economics (Haufe Online Redaktion, 2022).

In total, five different positions from the area of facility management were analyzed - in addition to the construction management as comparison group. Table 2 explains the positions.

Table 2 Jobs and job descriptions in Facility Management; job descriptions based on (Gondring & Wagner, 2018; Nävy, 2018).

Position	Job Description	Job postings / Companies
Object Manager	• Leads a team of specialist as a generalist • Responsible for the FM Service provisioning in the building • Face to the Customer • Employment usually with a service provider	400 / 370
Head of Object Management	• Lead of the Object Manager • More strategic viewpoint, monitoring of the quality and great requirements for soft skills • Contact person for the customer if on-site service does not work • Employment usually with a service provider	200 / 190
Facility Management	• Lifecycle-orientation of the building (from Design and Construction to Utilization Phase and Renovation as well as Demolition) • Strategic Viewpoint of the building (economical, sustainable, etc.) • Employment as a service provider or by owner	420 / 380
Head of Facility Management	• Lead of the Facility Managers • Strategic Viewpoint of the building and reconciliation with various stakeholders • Employment as a service provider or by owner	184 / 160

Position	Job Description	Job postings / Companies
Commission-ing Management	• Planning and Execution of the Commissioning Process • Responsibility for the Start-Up-Phase of a building • Support of the experts, logging and compilation • Employment usually with a service provider or construction company	11 / 10

By analyzing the job mentioned above, it is possible to take a range of different functional and task areas and levels of facility management into account.

Finding 1: Specific digital knowledge is not part of the job advertisements

All job advertisements were analysed on the digital skills mentioned. It is obvious that Microsoft Office is mentioned in the job advertisements – 796 job advertisements mention this software tool. Specific software for Facility Management, like ERP systems (315) or CAFM systems (198) are not mentioned as often as Microsoft Office skills. However, although they are specifically relevant for the service provision of FM services. In addition, other software tools and methods relevant to the Architecture, Engineering, and Construction (AEC) industry are also hardly mentioned. Especially BIM (5) and Calculation Software (23), which are standards in the AEC industry, do not play any role in the analyzed job advertisements. Figure 4 presents the results.

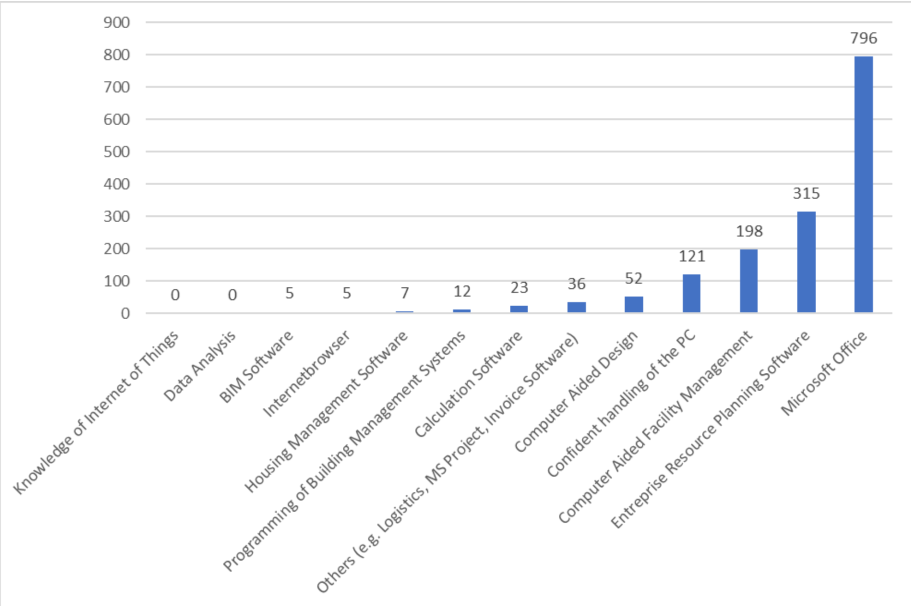

Figure 4 Number of times the respective software programs are mentioned in the job advertisements (n = 1,526).

The literature review shows that Data Analysis and Artificial Intelligence are critical success criteria in FM. The analysis of the job advertisements shows, that neither IoT, Data Analysis, nor skills in Artificial Intelligence was a relevant criterion in the FM job advertisements.

Finding 2: Requirements for MS Office Products skills depend on the profession

The analysis of job advertisements showed that Microsoft Office tools are especially requested in job advertisements that offer jobs within customer-based service provisioning. Especially in job advertisements for staff of Facility Management (85 %) and Object Management (77 %), the knowledge of MS Office products is relevant. In management positions and leaders, the requirements for skills in MS Office decrease. Also, in Commissioning Management, the percentage of job advertisements requesting MS Office skills is 9% low, as seen in Figure 5.

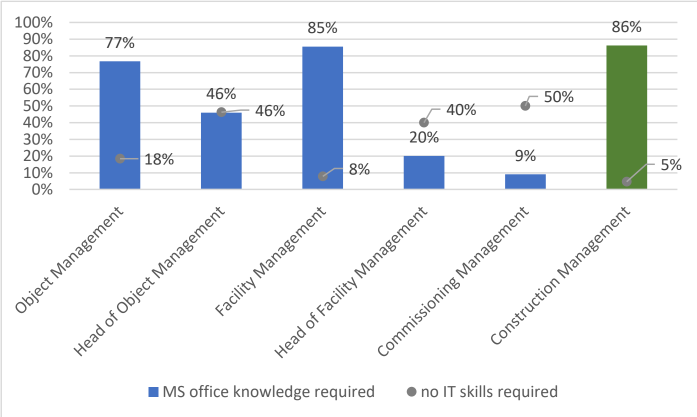

Figure 5 Required skills in products of MS Office (Percentage of job ads that require knowledge of Microsoft Office products (blue, requirements) and job ads that do not require any IT knowledge (gray, no IT skills required), n = 1,526).

Interpreting Figure 5, it becomes evident that MS Office products still manage a lot of service provisioning instead of using FM-specific software tools. To optimize data usage, it is necessary to gather all relevant data so that there is a requirement for other Software. Especially dynamic data cannot be effectively stored, analyzed, and appropriately processed with MS Office.

Finding 3: Uneven distribution of digitization in FM

While some companies already integrate IT skills in their job advertisements, other companies do not mention any relevant IT skills for the jobs offered, especially in jobs offered for Head of Facility Management (40%), Head of Object Management (46%), and Commissioning Management (50%). By comparison, the Construction Management figure is only 5%. The results are also shown in Figure 5. An analysis of the percentages shows that various factors influence these results. The company's size plays a crucial role in IT skills requirements - the larger the company, the more likely IT skills requirements exist. In the future, large companies, in particular, can offer the management of Smart Buildings and, thus, jobs with the SBM and the FDM. The company's orientation also plays a decisive role with regarding IT requirements - if the company comes from the technical sector, it has higher requirements than companies from the infrastructural or commercial sector. In the future it will tend to be companies from the technical sector that will have the operation of Smart Buildings and thus new jobs such as the SBM and the FDM. Companies that operate an internal FM generally have lower requirements for IT skills than companies that offer services - Although the IT skills and, thus, the opportunities for smart O&M of facilities tend to lie with the service providers, the analysis also shows that progressive owners already demand high IT skills when planning Smart Buildings. This means that both on the service provider side and the owner side, future new jobs that will be offered primarily by the service providers and thus support the primary processes. This shows that, bigger and more technical companies are able to operate and maintain Smart Building.

STEP 3: ANALYSIS OF APPLICATION OF DIGITAL TOOLS FOR FM IN STUDIES AND PRACTICE

To validate and discuss the results of the meta-analysis, a survey was conducted to learn what software tools are taught at the universities, what software tools are used by the students in practice and if the future generation of Facility Managers is capable of operating and maintaining Smart Buildings. The survey was conducted from 17.04.2023 to 28.04.2023 via an online tool. The survey started during lectures at four universities and nine courses. All in all, 166 students answered the questions. 159 of these students are studying in Bachelor courses, 7 students are studying in Master courses. 115 students worked in a student job besides their studies. The response rate was 52 %.

There is a difference between the job advertisements of the FM companies, the practice, and the content of studies. Figure 6 shows the difference between the three different software tools. BIM authoring tools are taught regularly at universities, so 74.6% of the students can use BIM authoring tools. 30.9% of the questioned answered that they also used BIM in their job. Nevertheless, only 0.3% of all analyzed job advertisements asked for skills in BIM tools.

Data Analysis shows comparable results: While 0.0% of all job advertisements asked for skills in Data Analysis, 17.0% of all participants answered that they already used tools for data analysis in their jobs, and 17.9% of the students received training in Data Analysis. Although 52.2% of all job advertisements asked for skills in MS Office products, 85.1% of all participants answered that they use MS Office regularly to conduct their services, and 76.1% of the students received training in MS Office.

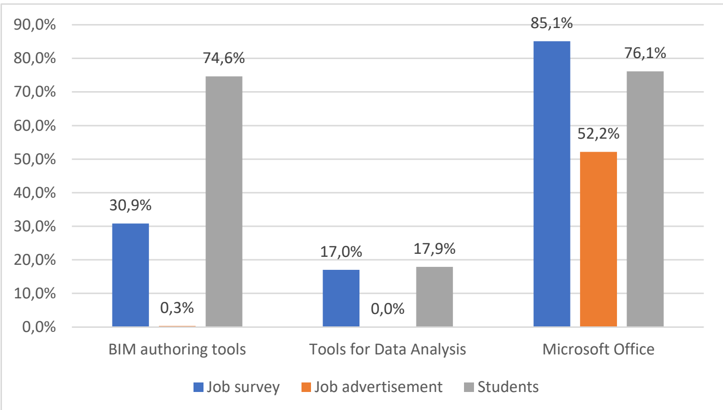

Figure 6 Comparison between students, practitioners and job advertisements for BIM authoring tools, Tools for Data Analysis and MS Office (n = 166).

As Figure 6 shows, a gap between the requirements of job advertisements, the taught tools, and the practice exists. This gap gets even more transparent by taking a closer look at the students' expectations.

The questionnaire asked the students about their expectations of the importance of various software tools and IT skills. Therefore, the participants rated various IT tools from 5 (very important) to 1 (unimportant). Figure 7 displays the results. The expectation on the importance of CAFM systems is as highly relevant as MS Office products (average rate of both = 3.99). In addition to that, data analysis is rated high, with an average rate of 3.85. The lowest average rate can be seen in IoT (3.27) and ERP (3.39).

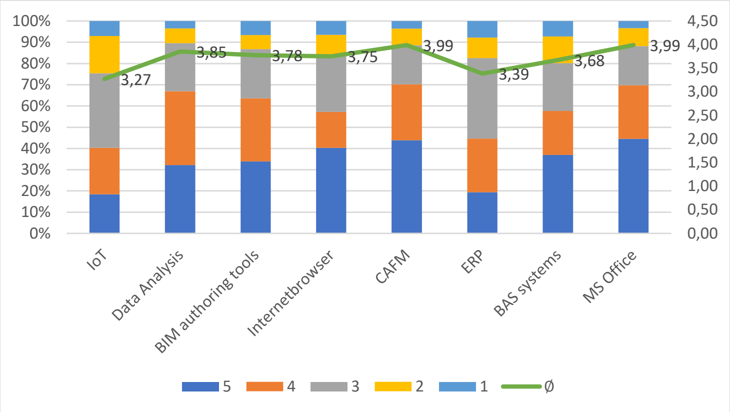

Figure 7 Expectations of the importance of IT tools for Facility Management (5 = very important, 1 = not that important, n = 166).

However, the results also show that the students have a high affinity for IT tools that enable the O&M of Smart Buildings.

STEP 4: DISCUSSION OF THE RESULTS

These results were discussed with students as well as employers. The students want to work with IT tools to improve the sustainability and efficiency of the O&M of buildings. They are interested in learning and implementing IT tools for special tasks, such as AR for maintenance or virtual training with VR. In addition, the students are familiar with the BIM method and data exchange formats, so they could quickly adapt their skills to future jobs. On the other hand, the discussions showed that many students are disappointed when working in their first jobs. This is caused due to a low expression of needed IT skills and - from the student's point of view – insufficient and consistent use of IT tools. Therefore, it will be necessary for employers to create jobs that meet the interests of students and fulfil the requirements of the future O&M of buildings, such as Smart Buildings. The discussions showed that this would increase the attractiveness of the FM industry. The results were also discussed with employers in the FM industry. The employers also would like to increase the use of IT tools and IT skills in the company. Some companies also stated that creating new jobs, such as the Smart Building Manager or the Facility Data Manager, will be relevant job positions in the future. Furthermore, robotics will become a critical IT skill in the future. On the other hand, they also stated that it is necessary to involve all employees and that in some areas, there is currently no need to include IT skills, such as sensors, Artificial Intelligence, VR, and AR or data analysis, as the focus is more on technical and manual skills. The integration of BIM data is the most crucial focus at most companies.

CONCLUSION AND OUTLOOK

This paper shows that IT skills in FM are differently seen depending on the orientation of the company, the questioned employers or students, and the size of the company. On the other hand, the paper also shows that integrating IT skills in the company's orientation is a vital success criterion for the FM companies, not only regarding the future service provisioning in Smart Buildings but also regarding the attractiveness for students. Therefore, the FM companies and the FM industry must transform themselves into IT- and data-driven technology companies. The implementation of Smart Building Managers and Facility Data Managers might be the first step in this transformation. This paper focussed on the German FM market, so that the results could not be automatically generalized to FM labour markets in other countries there is the need to expand the study with other European countries.

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Capturing As-Built Data to Support BIM-based FM: A Systematic Review

Ecem Tezel[1] and Heyecan Giritli[2]

ABSTRACT

Background and aim – Architecture, Engineering, and Construction (AEC) industries are gradually practising Building Information Modelling (BIM) to design and construct new buildings. The ongoing BIM transition within the AEC provokes BIM implementation by the FM industry. Although recent regulations enforce BIM utilization in new projects, most BIM models are not sufficient to support FM decisions. In addition, existing building stock across the world includes old buildings that are far away from having a BIM model. Literature advocates capturing as-built building data as a significant step for BIM-based FM.
Methods / Methodology – This study employs a science mapping procedure to analyse the existing body of knowledge within the domain of data capturing for BIM-based FM. It involves systematic data collection from scientifically reputable databases, followed by bibliometric analysis and visualization to (1) identify the most productive researchers and journals, (2) understand the key research themes, and (3) describe literature gaps.
Results – Findings reveal the most productive scholars from the United States, Germany, China and Hong Kong and the most productive journal as Automation in Construction based on the number of publications. The analysis highlights the integration of advanced technologies, data requirements and capturing standards, and BIM-based maintenance of heritage buildings as the trending research topics and proposes future research directions accordingly.
Practical or social implications – This study provides an overarching overview for FM practitioners by introducing the widely used as-built data capture technologies and guides researchers by helping to identify the key scholars, research trends, and knowledge gaps in this field.
Type of paper – Research paper.

KEYWORDS

Building information modelling (BIM), facility management (FM), data capturing, review.

INTRODUCTION

Implementing building information modelling (BIM) in the operational phase has become popular in the last decade. Yet, design and construction professionals are still taking the most advantage of BIM when delivering buildings. BIM refers to the use of a shared digital representation of an asset to facilitate design, construction, and operations processes to form a reliable basis for decisions (ISO, 2018), and is arguably the most promising tool to manage building information throughout the entire life cycle of a building (Becerik-Gerber et al., 2012; Mayo and Issa, 2016; Wijekoon et al., 2018; Dixit et al., 2019).

[1] Research Assistant PhD, Department of Architecture, Istanbul Technical University, Istanbul, Turkey, tezele@itu.edu.tr
[2] Emeritus Professor, Department of Architecture, Istanbul Technical University, Istanbul, Turkey

Every decision taken by the Architecture, Engineering and Construction (AEC) professionals in the design and construction phases substantially influences building operations. Therefore, the relationship between building delivery and building operations is more than a mere flow of time. The operational phase necessitates several facility management (FM) services to guarantee that the constructed facilities function efficiently, comfortably, and safely (Atkin and Brooks, 2021). FM activities carried out in this phase rely on the information scattered throughout the entire life cycle of a building (Wijekoon et al., 2016; Alnaggar and Pitt, 2019). Traditionally, building information is compiled as hard copies or electronic files that are, most of the time, incomplete, inaccurate, outdated or unavailable for further use. In addition, the manual data transfer process from discrete sources into the FM software is labour-intensive, tedious, time-consuming, error-prone, and most importantly vulnerable to data loss (Becerik-Gerber et al., 2012; Patacas et al., 2015). Each data loss leads to information discontinuity throughout the project life cycle (see Figure 1) and costs the building owner, especially for further phases such as the operations phase.

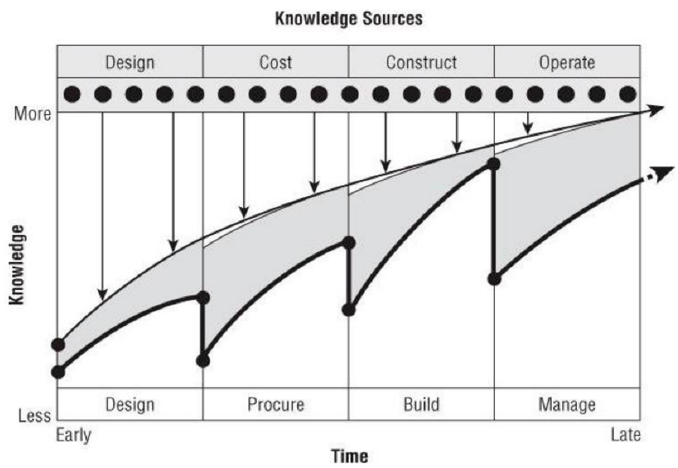

Figure 1 The BIM curve shows a loss of data without interoperability in project milestones (Source: Bernstein, [adapted from Read et al., 2012]).

The dire need for complete, accurate and available information in the operational phase features BIM as a beneficial tool for efficient information handling for FM purposes. However, the absence of as-built drawings is the greatest challenge of BIM-based FM in the first place (Volk et al., 2014; Soliman et al., 2022). Evidence indicates that BIM adoption is progressing faster in countries that mandate BIM (Ariono et al. 2022) yet, most of the BIM mandates focus on the use of BIM in building delivery rather than building operations. In addition, existing buildings constitute the biggest part of the FM portfolio that lacks proper documentation and BIM-compatible models. There are a variety of techniques and technologies for capturing existing building information and generating 3D models. This study aims to provide a holistic overview of the existing body of knowledge in the BIM-FM data-capturing field. It primarily explains the BIM information types for FM and introduces the three most widely used techniques for data capture and model generation. Then, employs a science mapping procedure to analyse the state-of-the-art within the domain of data capturing for BIM-based FM.

BIM INFORMATION TYPES AND TECHNOLOGIES TO GENERATE BIMs

Facility managers govern diverse sources of information to maintain required performance within the facility. BIM models (BIMs) can support facility managers in the decision-making process as they can minimize data-related problems by forming a repository for building life cycle data. The three fundamental information types that a typical information model involves are geometric, non-geometric (alphanumeric), and documented information, respectively.

Geometric information refers to the graphical representation of the building information in a digital 3D environment. Typical examples of geometric information of a building component involve its shape, length, width, height, angle, and so on. Accurate visualization of the facilities enables a quick understanding of all the assets, better management of the workspace, and supports refurbishment decisions. Alphanumeric information refers to the textual representation of the building information and is often recorded as spreadsheets or tables. Typical examples of non-geometric information about a building component involve its ID, manufacturer name, installation date, colour, material, cost, and so on. This type of information is not suitable to visualize but is crucial when performing preventive, predictive or corrective maintenance activities, making replacement decisions or monitoring the inventor. Finally, documented information refers to the documents attached to the building components. Typical examples of documented information involve O&M manuals, warranties and specifications, contracts, and so on. BIMs allow attaching documents to the model objects so that the responsible actor can check the operations manual or performance specifications of each asset using the same digital model.

Identifying, retrieving and processing proper data for efficient FM practices has been one of the main competencies of FM teams and one of the primary concerns of BIM-FM researchers. Even though simple geometric 3D models are not complete BIMs, they are critical to achieving BIM-based FM. Therefore, it is essential to utilize the most appropriate technology to generate 3D digital copies of real-life facilities. The next sections briefly introduce the three major techniques to generate geometric building information for BIM-based FM.

Photogrammetry

Image-based techniques refer to the generation of 3D building models by capturing existing building information using photos and videos. Photogrammetry is the most widely known image-based data capture technique that involves the utilization of 2D digital photographs for creating 3D building models (Bhatla et al., 2012, Klein et al., 2012). High-resolution digital photographs of a specific object or building are taken with the help of cameras that are carried by hand (i.e., handheld cameras), by a robot (i.e., remote control vehicles) or by an unmanned aircraft (i.e., drones). This technique enables measuring inaccessible locations (higher stories, etc.), reduces work on-site, and provides more accurate measuring (Klein et al., 2012, Hellmuth, 2022). However, the accuracy of the photographs depends on adequate lighting conditions, the selection of appropriate cameras and lenses, and the level of expertise in image acquisition (Volk et al., 2014; Hellmuth, 2022).

Laser scanning

Laser scanning or LiDAR (Light Detection and Ranging) is a widely used technique to capture as-is data of existing buildings. They generate the geometry as point cloud models and provide a high-quality representation of the actual buildings (Hellmuth, 2022). A point cloud refers to an accurate and dense set of points (Krämer and Besenyoi, 2018) and is generated with the help of the light beams emitted from the laser scanner. The scanner is positioned at different locations of the building that is to be modelled. Laser scanners ensure a high level of accuracy and precision when modelling as they scan the area or volume using millions of points in a significantly short time. Still, their equipment requires high investment and maintenance costs and necessitates experienced labour to capture accurate data regarding the building.

3D modeling

Manual techniques for generating building information refer to the utilization of pre-existing building information (Volk et al., 2014). This technique involves gathering all relevant information about the building in any form and using specific BIM software such as Autodesk Revit, ArchiCAD or Nemetscheck Allplan to create a 3D model of a building. Examples of existing information sources are architectural drawings, structural plans, MEP plans, and technical specifications. Compared to the previous methods, manual information generation techniques are easier to use as they rely on available documents. However, due to several reasons, most buildings do not have well-kept archives regarding their physical aspects (Hellmuth, 2022). As a result, they require experts skilled in 3D modelling to capture measurements and dimensions on-site and create 3D models of each asset by hand. Therefore, manual techniques are more labour-intensive, prone to human error and time-consuming than other techniques (Volk et al., 2014; Hellmuth, 2022; Soliman et al., 2022). Furthermore, these techniques are not suitable for large-scale projects or buildings with complex geometric shapes.

All these technologies have their specific strengths and drawbacks in terms of speed, accuracy, practicality, technology requirements and labour skills. Although none of the techniques is superior to each other, the combination of image-based and range-based techniques can leverage the data capture and model generation process. It is important to note that, it is not a matter of adopting a single technology or software when implementing BIM for FM. Rather, there is a strong need to understand the BIM phenomenon and a data-driven mindset for the full utilization of BIM.

RESEARCH METHOD

The primary objective of this study is to analyse the state-of-the-art within the domain of data capturing for BIM-based FM. To achieve its objective, this study applies a science mapping procedure, which refers to a two or three-dimensional representation of a science field (Noyons, 2001) that illustrates the interconnections between research topics, scholars or publications on a map. Initially, the systematic search of the scientific literature on two major databases, namely Scopus and Web of Science filtered the publications containing ("building information model" OR "building information modeling" OR "building information modelling" OR "BIM") AND ("facility management" OR "facilities management" OR "FM") AND ("as-build" OR "as-built" OR "as-is" OR "as-designed" OR "as-constructed"). Irrelevant studies and duplicates were discarded after a thorough screening process. Then, the bibliometric analysis identified the most productive researchers and peer-reviewed journals and outlined the mainstream research topics of BIM-FM data capturing. VOSviewer software version 1.6.19 was employed to graphically visualize the bibliometric analysis results. Finally, knowledge gaps are described in the existing literature and further research directions are proposed.

FINDINGS

The initial search on the Scopus and Web of Science databases detected 98 and 78 publications, respectively. A total of 176 publications published between 2008 and 2023 were further monitored to eliminate duplicates and irrelevant studies. Finally, 100 publications including 58 journal articles, 4 book chapters and 38 conference papers were selected for bibliometric analysis. Figure 2 represents the distribution of the publications over the years.

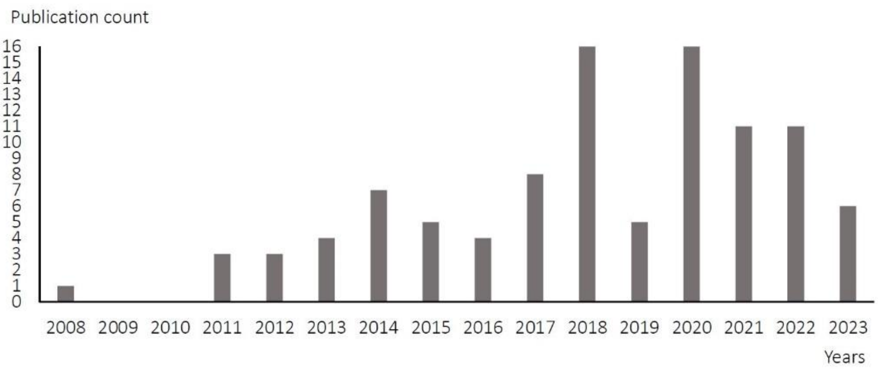

Figure 2 Publications over the years.

Although there is a consistent distribution of publications, the graphic does not indicate a continuous increase or decrease trend in the studies focusing on data capturing for BIM-based FM. As seen in Figure 2, 2018 and 2020 emerge as the years with the highest publication counts of 16, whereas 2008 represents the lowest count of 1. Detailed analysis of the journals reveals that Automation in Construction accounted for almost a quarter of the articles with 14 articles, followed by Journal of Facilities Management (3), Advanced Engineering Informatics (2), Applied Sciences (Switzerland) (2), Buildings (2), Built Environment Project and Asset Management (2), Engineering Construction and Architectural Management (2), Journal of Computing in Civil Engineering (2), and Journal of Construction Engineering and Management (2).

The bibliometric analysis of the selected papers reveals that there are 285 authors in the field of data capturing for BIM-based FM. Figure 3 represents several clusters within the author community. These clusters seem disconnected, yet they result from the wide range of topics involved within the field. In order to identify the most productive scholars, the number of documents published by an author is used in the analysis. It is found that more than 80% (230) of the authors have appeared in a single publication, while the remaining 55 authors have more than two publications. However, due to the space limitations, authors who have at least three publications are displayed in Table 1.

As seen in Table 1, the United States, Germany, China and Hong Kong are the principal countries publishing research in the BIM-FM data-capturing field. Semiha Ergan at New York University and Burcu Akinci at Carnegie Mellon University have the highest number of publications, 6 and 5, respectively. Their studies focus on identifying FM-specific information items in as-built BIMs (Dias and Ergan, 2016; Dias and Ergan 2021), generating as-built BIMs by leveraging existing data sources such as images, PDFs, CADs and Docs (Gu et al., 2014a, 2014b) and laser scanners (Gao et al., 2012, 2013). The remaining top scholars have 3 publications. Among these authors, Walid Thabet at Virginia Polytechnic Institute and State University focuses on defining data requirements and data transfer procedures for BIM-based FM (Thabet and Lucas, 2017; Lucas and Thabet, 2018; Ensafi et al., 2022). Vladeta Stojanovic and Matthias Trapp at Hasso-Plattner-Institut für Softwaresystemtechnik and Jürgen Döllner and Rico Richter at Universität Potsdam utilize mobile devices to capture indoor 3D point clouds and analyse the deviations between as-is and as-designed BIMs (Stojanovic et al., 2018a, 2018b; Stojanovic et al., 2019). Jack C.P. Cheng at the Hong Kong University of Science and Technology and Wang Qian at Southeast University also utilize laser scanners to automatically generate as-built BIMs (Yang et al., 2020; Wang et al., 2021; Wang et al., 2022).

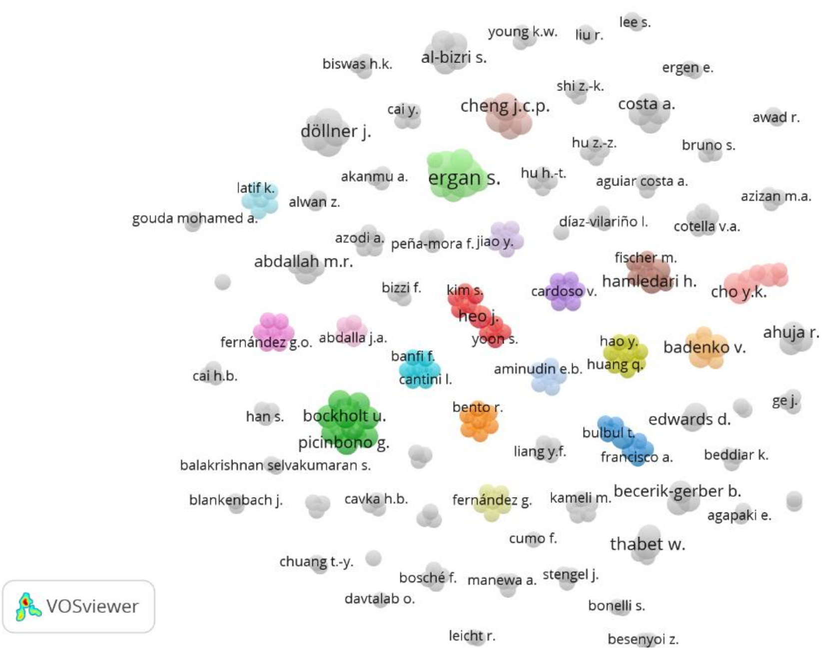

Figure 3 Visualization of the co-authorship analysis results.

Finally, the keyword co-occurrence analysis identified 246 unique keywords, which represent the major concepts studied in the selected publications. Approximately 80% of the keywords appeared only once, therefore, author keywords with a minimum of 2 occurrences, which corresponds to 20% of all keywords, were selected to identify the key research topics. As a result, 48 of 246 keywords were identified and visualized in Figure 4.

Table 1 The most productive scholars in the BIM-FM data capturing field.

Author	Publ.*	Institution	Country
Ergan, Semiha	6	New York University	United States
Akinci, Burcu	5	Carnegie Mellon University	United States
Döllner, Jürgen	3	Universität Potsdam	Germany
Richter, Rico	3	Universität Potsdam	Germany
Stojanovic, Vladeta	3	Hasso-Plattner-Institut für Softwaresystemtechnik	Germany
Trapp, Matthias	3	Hasso-Plattner-Institut für Softwaresystemtechnik	Germany
Cheng, Jack C.P.	3	The Hong Kong University of Science and Technology	Hong Kong
Wang, Qian	3	Southeast University	China
Thabet, Walid	3	Virginia Polytechnic Institute and State University	United States

As seen in Figure 4, selected keywords are grouped into 10 clusters according to their interrelatedness. Each cluster refers to a research theme and guides researchers to find both highly studied and neglected areas within the field. Results of the keyword co-occurrence analysis reveal that generating BIMs and digital twins based on 3D point clouds and IoT data is one of the emerging research topics. As indicated by Mannino et al. (2021), there are several challenges to be addressed when integrating BIM and IoT including standardization in data capturing, real-time data management, and utilization of open data standards. Although the literature has several studies involving those keywords, the research is in the early stages.

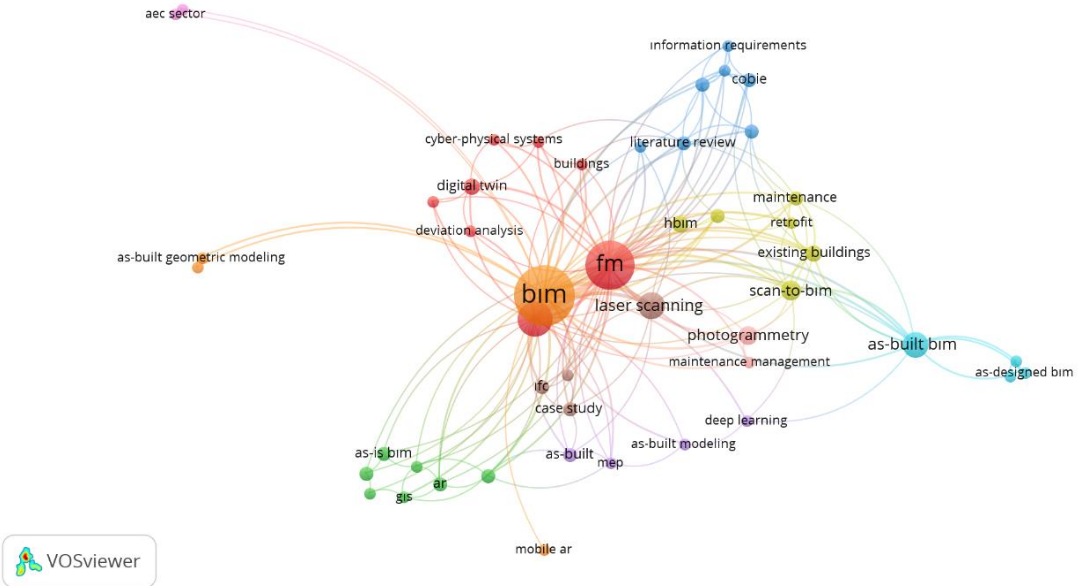

Figure 4 Visualization of the keyword co-occurrence analysis results.

The second popular research theme involves studies utilizing as-is BIMs and different information technologies such as AR and GIS for the operation and maintenance of various facilities. It is evident that those technologies can help project stakeholders store, manage, access, retrieve, and update project data at different stages of the project and facilitate better communication between stakeholders (Sharafat et al., 2021). A third cluster involves studies prioritizing the management of building information by means of the identification of information requirements and exchange procedures. As a pioneering study, Teicholz (2018) provides a BIM-FM integration guideline for owners and facility managers. In addition, an in-depth analysis of the existing literature, standards, and best practices and a questionnaire survey with FM experts conducted by Matarneh et al. (2020) identified the required information to support BIM-based FM. Finally, the fourth cluster involves keywords such as "scan-to-BIM", "HBIM", "maintenance", "refurbishment", and "retrofit". This group involves both theoretical and case-based studies focusing on the use of data-capturing technologies for existing buildings, with a specific interest in historical/heritage buildings. The remaining clusters have fewer and less frequently occurring keywords, therefore they are yet to be claimed to represent a special research trend.

Table 2 The 10 most occurring keywords.

Rank	Keyword	Occurrences	Average publication year
1	BIM	54	2019
2	FM	35	2019
3	Point cloud	18	2019
4	Laser scanning	11	2017
5	As-built BIM	10	2016
6	Scan-to-BIM	6	2020
7	Photogrammetry	5	2018
8	Existing buildings	4	2019
9	Digital twin	4	2020
10	HBIM	4	2020

Table 2 shows the 10 most occurring keywords together with their average publication years as follows: BIM (54; 2019), FM (35; 2019), point cloud (18; 2019), laser scanning (11; 2017), as-built BIM (10; 2016), scan-to-BIM (6; 2020), photogrammetry (5; 2018), existing buildings (4; 2019), digital twin (4; 2020), and HBIM (4; 2020). These results of the keyword co-occurrence analysis can guide researchers to identify research trends as well as the literature gaps.

From the table, it is visible that generating as-built BIMs by range-based data-capturing technologies is a relatively old and highly studied area of research compared to other topics. Yet, the literature lacks studies focusing on the use of image-based technologies especially for the digitization of heritage buildings and their maintenance. Thus, future research on the following topics is encouraged by this research: (1) comparison of the strengths and drawbacks of various data capturing technologies and developing implementation procedures to support BIM-FM transition, (2) automated and streamlined data transfer between different sources to generate FM-specific BIMs and digital twins, and (3) case studies and best practices utilizing BIM-FM technologies on the existing building stock.

CONCLUSIONS

It is only natural for the quantity of information to increase from the early stages of building delivery to building operations. The vast majority of information generated during delivery becomes invaluable assets for FM professionals. However, traditional information delivery procedures cause information loss and convert digital information into analogue formats. Considering the fast-approaching BIM for FM phenomenon, it is essential for building owners and FM representatives to understand and adopt relevant methods and technologies to ensure smooth implementation.

This paper employed a science mapping procedure to analyse the existing body of knowledge in the BIM-FM data-capturing field. The systematic search of the literature identified 100 studies published in peer-reviewed journals, books and conference proceedings. The bibliometric analysis identified the most productive scholars and institutions, relevant journals and trending research topics. The results of these analyses also unveiled the knowledge gaps and proposed further study opportunities in the BIM-FM data-capturing literature.

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Multilocational work culture – the use of flexible spaces and the new paradigm of work in university support services

Sykäri, M. [1], Nenonen, S. [2], Nurmi, N. [3], & Sandström, N. [4]

ABSTRACT

Background and aim – Multilocational work challenges university organizations on the individual, team, and organizational level. The goal of this study is to understand the impact of multilocational work of university support services.

Methods / Methodology – The research is explorative. Methods include a work culture case study and two supportive surveys in the university. Data was gathered by observations, document analysis and interviews. The analysis was based on identifying significant datapoints from the rich data. The classification and qualitative coding provide the data-based patterns of multilocational work culture.

Results – The results indicate some patterns of multilocational work culture. One is community-driven choices to come to the office on campus. The workplace transformation creates a subculture and a pattern of fear of losses. The fear is diminished by giving the users the mandate and role to manage the multilocational workplace experience.

Originality (if applicable) – The novelty of the research is based on data collected mainly during the post-Covid period and in laying the foundations of understanding how to succeed in facilitating the return to campus.

Practical or social implications – The practical implications for facilities management underline the importance of acting as a change agent in the transformation of working culture. The results indicate that the patterns appear on diverse levels in terms of change resistance. Future studies about the layered working culture can specify the phenomena in diverse cultural layers of academic workplaces.

Type of paper – Full research paper

KEYWORDS

Workplace, culture, covid, patterns, transformation, layers, university support services.

INTRODUCTION

The COVID-19 pandemic has caused significant disruptions to the work practices of university staff (Watermeyer et al., 2022). Many opportunities for understanding the new needs of academics and imagining the future of research environments can be drawn from the experience of research work during COVID-19 (Tagliaro et al., 2022). The pandemic has given impetus to a new narrative of work in universities, which promotes integrated and agile forms of working, transcending the 'boundary-blocks of status-based traditions (Watermeyer & Rowe, 2021).

[1] Department of Industrial Engineering and Management, Aalto University, Helsinki, Finland Maikki.sykari@aalto.fi
[2] University of Helsinki, Finland
[3] Department of Industrial Engineering and Management, Aalto University, Helsinki, Finland
[4] Department of Education, University of Helsinki, Finland

As a result, work-based polarisation may potentially decline, with spaces of ritualistic and performative interactions receding and giving way to new spatio-relational dynamics based on trust. These dynamics can help dismantle role prejudices and improve role recognition (Gray, 2015). The evolving changes in working culture for research, teaching, and administration within universities will also influence the practices of facilities management.

The goal of this study is to explore the impact of multilocational work on academic working culture, with a specific focus on university support services and activity-based offices. The research question asked is: How is academic multilocational work experienced in university support services and among professional service staff? The special interest is in using sociocracy-based workplace change process methods. One unit in the university support services decided to experiment the use the sociocracy method in supporting their relocation to a new building. The unit was chosen as a case unit by theoretical sampling. The case study unit represents support services e.g., functions like accountancy, human resources, communication, and information and communication technology.

The paper continues with insights to remote work in universities, followed by a description of the research design, methodology, and findings, offering insights into the experiences and implications of multilocational work in the context of university support services. Finally, theoretical and practical implications are discussed.

REMOTE WORK IN UNIVERSITIES

Academic work culture and multilocational work

The increasing trend of knowledge workers adopting remote work, even before the COVID-19 pandemic, has been a prominent focus in many research agendas (e.g., Allen et al., 2015). Academic work as knowledge work is more complex, and knowledge creation rarely happens in solitude in an office, but rather in many different interfaces (Indergård et al., 2022). These interfaces might be with colleagues or students during fieldwork, laboratory work etc. (Macfarlane, 2010; Teichler et al., 2013). Although telework and online education have become increasingly popular since the emergence of the Internet, the COVID-19 pandemic made educational institutions worldwide switch to them overnight. As modern knowledge work highly relies on effective interaction, fostering community creation has become a core purpose of the workplace design (Heerwagen 2004).

Haynes (2012) posits that in-person interactions within physical spaces lead to the development of stronger social ties compared to those formed remotely. Furthermore, knowledge tends to flow more smoothly in a work community when trust is established among its members. Heerwagen (2004) adds that knowledge work hinges upon the creation, sharing, and application of knowledge, necessitating collaboration. Achieving the right balance between collaborative and individual spaces in university settings is crucial, as is determining the optimal balance between on-campus and off-campus work locations (Tagliaro et al., 2022).

The traditional academic workplace has been transformed, initially into a remote environment, typically at an individual's home, and later into a hybrid one that combines remote and face-to-face work (Stefanova & Zabunov, 2022). Although various academic disciplines have distinct requirements for collaboration, Huhtelin and Nenonen (2019) found that many scholars need a balance between concentration and interaction to effectively conduct their research activities. Nordbäck et al. (2021) argue that places, social entities, and temporalities intertwine as sources of identity. For understanding academic identities, it is useful to examine the interplay between layers of place (spaces such as city neighbourhoods, buildings and workspaces that are made meaningful by people), social aspects of identity (such as academia, university, department, research group, and research collaborations), and different temporal orientations (past, present, and future).

Poutanen (2021) suggests that organizational spaces can be seen as distinct domains of material, social, experienced, and digital space. Consequently, the process of users' actions (occupying, feeling the space) creates the complex socio-technical system that constitutes organizational space. Universities had already implemented alternative work environments before COVID-19 pandemic. Berthelsen et al. (2018) investigated the psychosocial work environment in academia after moving to activity-based work environments, discovering that the social community at work had diminished and the perceived social support from colleagues and supervisors had decreased. As the work environment shifted to home, Pakos et al (2021) found that in the post-pandemic “new normal”, the choice of work location will more frequently be based on the type of activity. Marzplan et al. (2022) concluded in their review that the shortcomings of activity-based offices lie not in the concept itself but rather in the implementation and use of the premises. Tailoring solutions to each organization and considering individual differences can increase the likelihood of success (Marzplan et al 2022). Watermeyer et al. (2022) address the potential of remote working as a means of fostering boundary crossing, social connectedness, and trust relationships in universities both in the immediate context and the anticipated post-pandemic future. For the most part, working relationships seem to have remained the same – however, there is evidence that remote working has both improved and worsened professional service staff’s relationships with academics (Watermeyer et al., 2022).

Poutanen et al. (2021) investigated professional service staff, focusing particularly on remote work on campus. They found that the quality of mobility in a dispersed academic community is mainly intra-organisational. The reasons for mobility include: 1) interaction and collaboration within the academic community, 2) provision and missing affordances of the workspaces, and 3) increasing work-life balance and control over work time and environment. However, despite the disruptions brought on by the pandemic-driven transition to remote working, universities as fields of interaction may prove resistant to any substantive reorganisation of their professional services in the long term. The boundary-crossing potential of remote-working may remain untapped in both the immediate and post-pandemic context — whenever the latter occurs (Watermeyer et al., 2022.)

Watermeyer et al (2022) reported that 47% of respondents in their study indicated that remote working increased the productivity of professional services staff in studied universities. In their recent review, however, Hill et al (2022, p.29) found that virtual work may also lead to negative outcomes, such as "social and professional isolation, poorer quality relationships, reduced boundary control, and work intensification." Occasional visits to the office can help remote workers minimize feelings of isolation and detachment from the organization (Allen et al., 2015), strengthen social ties and foster a sense of belonging (Fonner et al., 2010), as well as reduce the likelihood of cyberslacking or disengagement. Working in an office environment also facilitates a more structured work schedule, allowing for clear distinctions between work and personal time, and reducing the chances of work encroaching on personal life (Golden et al., 2006). Moreover, the office environment typically offers access to resources, tools, and support systems not readily available in remote work settings. This access can enhance work efficiency and productivity, decrease the need for overtime, and provide more personal time. Waber et al. (2014) further highlight the significance of random encounters and serendipitous interactions in physical office spaces, which can foster innovative ideas and collaboration.

Practices to develop work environment

Already before the pandemic the process factors or implementation were seen important in activity-based flexible offices (Rolfö 2018). Employee participation and empowerment, allocation of resources both in time and economically as well as open communication were some of the stated factors by Rolfö (2018). Sirola et al (2021) argue, that high quality of change management is required, particularly regarding communication and user participation in terms of real decision power. Sirola et al (2021) found in their study that user participation occurred, but it only raised false hopes and led to a negative outcome. Together with Rolfö (2018) this means that communication and participation are both important and they need to be taken seriously and give implementation process the resources needed as well as real decision power. The need for employee-created, explicit rules in activity-based offices became clear in Babapour Chafi and Rolfö's study (2019). When people move from private offices to activity-based offices, extra care is needed (Sirola et al 2021). Specifically, Haapakangas et al (2018) found that if the number of quiet rooms was low, several negative outcomes were found.

The covid-enhanced remote work will likely alter the organization's needs from allocated spaces towards shared use of facilities. The innovative ways to use facilities require a novel approach from facilities management: how to achieve the sufficient usage rate, how to support encounters, interaction, and collaboration within the community (Poutanen et al., 2021). The requirements of a digital transformation (He et al. 2023) and data driven approach to the management of campus are needed. Additionally organisational resilience (D'Orazio et al., 2022) drives the changes in facilities management. Next to increased work-life balance academics are also recognising the value of more flexible working conditions to (attracting and retaining) a diverse work demographic and universities fulfilling an environmental commitment (Watermeyer et al., 2022).

Moreover, if we consider psychosocial risks, tailoring the workplace according to the demands from the workforce is beneficial, according to Armitage and Armar (2021). The three dimensions of work-life balance, work-life fit and work-life integration must be considered to reduce the risks (Armitage & Amar 2021). Roskams et al (2021) suggest that to compensate the top-down strategies in providing working environments, they should be accompanied by a bottom-up approach. In this approach, the users are involved and are empowered. Thus, they can make decisions to adapt the space to their needs.

One bottom-up approach to participatory workplace change process is Sociocracy 3.0 -method (Sociocracy 3.0, 2023). It is a collection of social tools for participative strategic decision making. They are interlinked to the elements from e.g., from sociotechnical design, IT-design, and HR-design to contribute to the practice of the New World of Work (time and place independent work) (van Amelsvoort and Van Hootegem, G. 2017). The method is inspired by sociocracy governance and includes practices like four elements of circles, consent decision-making, double linking, and elections (Owen & Buck, 2020). The Sociocracy 3.0 methods, especially consent decision-making means that decisions are made using a certain process. Needs and concerns are collected before and during decision-making workshops. To be qualified as an objection, an argument must reveal a risk in implementing the proposal or present an improved version of it. In contrast to a majority vote, even a single objection can overturn the proposal, but only if it is qualified. The proposal needs to be amended to address the qualified objections. Thus, a valid objection could halt the process unless an improved decision is accepted. This method was used in the case study described in the following chapter.

RESEARCH METHODOLOGY

The research is explorative by nature. Methodologically, the research followed a mixed method approach (Figure 1). The qualitative study, a case study of sociocratic process with the context of workplace change in one university service unit during 2022 and spring 2023 provided the qualitative data set. Data was enriched with observations and document analysis in workplace transformation process in the case study. The data is analysed, comprising the case study part (Flyvbjerg, 2011).

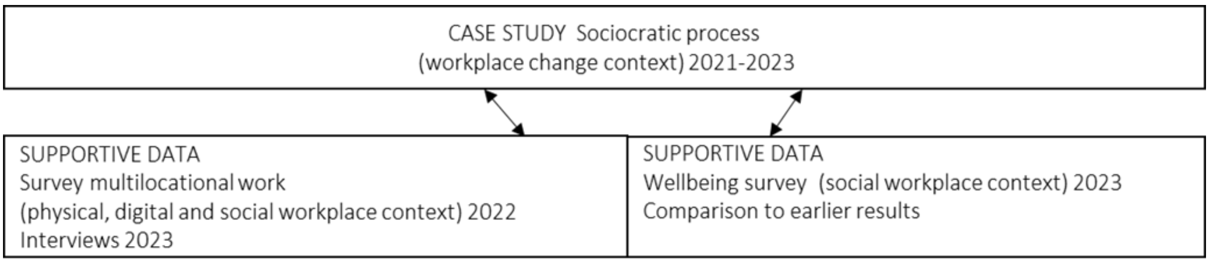

Figure 1 Data gathering approach.

Case study: Sociocratic process

The case study was a work culture project, supporting one university professional service unit during their internal transition to new premises (n= 162 employees) and new ways of working after COVID-19 pandemic. The transformation from small, assigned office rooms to activity-based offices (ABS) took place in 2022. Decision-making power over two domains – principles of hybrid work in general, and practices in the new office building – were given to personnel. As this was a new way of working for them, the unit chose Sociocracy 3.0 because it had a pattern, called consent decision-making, that suited the circumstances. Facilitators were also available to guide personnel in this new practice.

The first method used were twelve workshops, in spring 2022 conducted on-line. In autumn 2022 the case study unit started experimenting with an asynchronous consent decision-making process, to reduce the number of resource-intensive workshops used in the earlier phase. The data-analysis included the clustering of the workshop results based on the content and quality of the decisions. The second data set was collected from document analysis in workplace transformation process in the case study. The asynchronous process was based on facilitated online discussions and polls that were available in the unit's Teams channel. The tools used were based on Sociocracy 3.0 -methods. The data was analysed based on the documents of the process according to the thematic clusters in the first phase. The third data set was gathered after removal including the workshops, observation, and a feedback survey. In autumn 2022 and spring 2023 two workshops and two asynchronous consent decision-making processes were conducted. One of the authors was a participant observer in the case study unit.

The supportive quantitative and qualitative data was collected from two larger surveys conducted in the university. It was possible to analyse the results of the case unit as a part of the total dataset.

The multilocational work survey prepared and conducted by the representatives of human resource management, information and communication technology and facilities management of the university in September 2022. It was an online survey to the stakeholders directly involved in academic activity: faculty staff and administrative staff. 2995 respondents took part, of which 50 % were lecturers, and 50 % administrative staff from the case study university. Overall, the number of respondents were 30 % of the total number of employees. The survey was aimed at studying the respondents' attitudes and perceptions related to multilocational work and the physical, digital, and social work environments. The survey included twenty-six questions based on a 5-point Likert scale, one multiple choice question, six open questions and thirteen background factor questions. The statistical analysis was conducted and the case study unit results were compared with the total data.

The goal of the workplace wellbeing survey, conducted every other year at Finnish universities, is to shed light on the state, strengths, and development targets of staff wellbeing in the university as a whole, as well as in its faculties, and departments. It helps to focus on the aspects of workplace wellbeing in need of improvement within the University and its units. The survey provided an apt source for workspace wellbeing data about the whole university that included longitudinal data from previous years. The online survey of wellbeing included nearly 100 5-point Likert scale statements connected to resources, communication, and management as well as stress, mental health, and ability to work. In the case unit, one survey question was studied for validation using interviews in May 2023. Participants were randomly chosen from employees who worked in the new building. Two people declined and four were interviewed.

RESULTS

The empirical data provided response to the research question: How the academic multilocational work is experienced in university support services and among professional service staff? The case unit workplace changes and work culture process were based on Sociocracy 3.0 -method. The workplace's change to activity based working environment was a process where especially consent-based decision making was used. The process included thirty-six policy decisions made in June 2022 during three workshops. All decisions had specific checkpoints when the concern-based metrics and other feedback were re-evaluated. The unit moved to the new premises in August 2022.

The results showed that a couple of concerns had been actualized according to several survey respondents, but most concerns had not been actualized according to the majority. This gave a positive signal, in addition to the feedback, that people were quite satisfied with the premises. The second round of decision making in November 2022 provided an opportunity for people to consider some new proposals, and to propose improvements to agreements made in the June 2022 workshops.

Especially interesting changes were implemented regarding the flexi zones. In the initial planning stage of Spring 2022, a lot of concerns had been raised about noise and distractions in flexi workplaces. Thus, it was reasonable to originally stay on the safe side and allocate a lot of quiet zones in the beginning, remaining open to later adjusting the zoning based on real usage. Metrics of flexi desk usage were collected via network traffic statistics associated with each flexi desk. The metrics supported the growing consent on needing more co-working spaces than originally allocated, and less spaces for silent work. As a result, some zones were flipped from quiet to co-working to match the need. Other minor improvements to the zone etiquette were implemented as well, making the rules easier to understand and adhere to. Results indicate that the consent decision-making had a positive effect on the work culture and hence supports the previous findings in literacy.

The supportive data from multi-locational work survey complements the case study (Figure 2). Most respondents in the case unit agreed that they can influence the practices used in multi-locational work (fully or tend to agree). This applied to university in general as well as to the case unit. The university's guidelines for remote work were seen much more negatively in this unit than in the university in general. Similarly, multilocational work was not seen as natural part of work than in average.

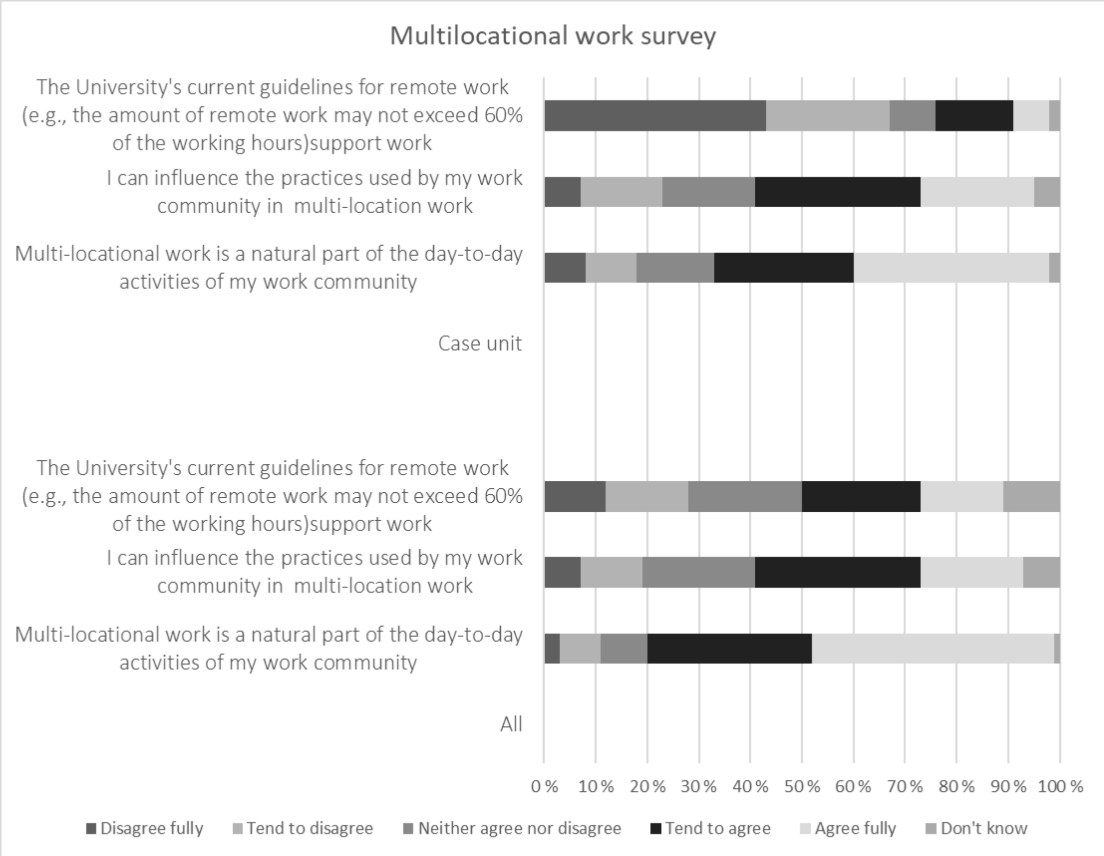

Figure 2 The social work environment.

The possibility to follow up the development can be seen from the wellbeing survey by comparing the earlier results with the latest gathered in spring 2023 (Table 1). The long-term data about the development of possibility to concentrate without too many disturbances indicates that from year 2017 to the present year 2023 there has been increase of the experienced possibilities.

Table 1 University well-being study, question "I am able to concentrate on my job without excessive disturbances." .

Year	Mean in the case unit (1-5)
2017	3,2
2019	3,4
2021	3,96
2023	3,87

The statement about the possibility to concentrate got higher ranking in the year 2023 in the activity-based work environment than in the former office with more private rooms. In 2023 hybrid work practices allowed employees to work from home and thus part of the higher ranking might be due to the possibility to work remotely.

During spring 2023 four interviews were conducted to validate the response to the statement in the multilocational work survey: "I can influence the practices used by my work community in multilocational work "(Figure 2). The themes of the interviews were the experiences of individual influencing, human resource practices and new workplace patterns. One of the interviewees expressed general discontent about the work in office, especially in the new premises. This interviewee stated that the sociocratic process started too late, when it had already been decided that the unit would move to ABS office. Thus, this confirmed that there was initial dissatisfaction. However, two of the four interviewees stated that they would have given a more positive answer if the question had been about the sociocratic process. This supports the findings of Sirola et al (2021) that real decision power must be given to employees or there will be danger or raising false hopes and even negative outcome can occur. In this unit, the decision power was real and appreciated by many but came later in the process than would have been ideal.

CONCLUSIONS

The goal of this piece of research was to understand the impact of multilocational work on academic working culture, especially in the context of university support services, which was presented by the case study unit. It not a new finding that it is essential to involve users to co-design in workplace development however the method sociocracy used in this research is a new lead to co-creation of work practices in the context of workplace change. Specifically, it describes a way to make participatory decision in an organization. The emphasis is more in social place than in physical and digital place solutions. This is interesting especially now when the experiences in closed campus during the pandemic period increased the awareness of multilocational work. Individual concentrative work has changed from office-based context to a wider and multilocational context as work-from-home or office-based work can be chosen according to work processes. The significance of social work environment is increasing.

The research contributes to academic workplace research especially in terms of methods for co-creation of flexible workplaces. The context of social workplace was identified important. The results encourage to investigate and develop campus as a source for diversity of meeting. Traditionally university has been leaning on individual impact and the requirements for the work environment follow that line. The shift from campus working to multilocational working makes diverse cultural layers visible in academic workplace culture and one needs to get more insights to diverse layers in physical and digital workplace context. It is possible to get more understanding how individual productivity might develop towards team-based productivity.

The weakness of this study is in the comparability – it would have been interesting to compare several organisational units – especially when there is survey data for that. However, the change process took place only in one unit in the suitable timescale for gathering the data.

The practical implications for facilities management underline the importance of acting as a change agent in the transformation of working culture. The results indicate that the patterns appear on various levels in terms of change resistance. Future studies about the layered working culture are needed to specify the phenomena in diverse cultural layers and in different subgroups of academic workplaces.

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Comparing the influence of cultural values on workspace perceptions of German and Turkish knowledge workers

Thomas Vogl[1] and Marko Orel[2]

ABSTRACT

Background and aim – The onward march of globalization led to a growing interest in understanding the interplay between cultural values and workspace perceptions. This research endeavors to elucidate how cultural differences between Germany and Turkey shape workspace perceptions of knowledge workers. The overarching objective was to understand how these cultural values are perceived to influence the working environment in both nations.

Methods / Methodology – A comparative survey analysis was executed among office workers in Germany and Turkey, probing into their workspace design preferences and their sense of well-being at work. Responses were contextualized with established cultural dimensions, particularly individualism vs. collectivism and uncertainty avoidance.

Results – The analysis pointed towards evolving workplace dynamics, with teleworking gaining traction in both countries. Intriguingly, there existed a discrepancy between cultural values and workspace preferences. Despite Germany's common portrayal as individualistic, there was a subdued preference for individual offices when contrasted with Turkey, often classified as collectivist. Additionally, the cultural dimension of uncertainty avoidance played a significant role in influencing working time preferences.

Originality – This investigation delves into a relatively uncharted territory, questioning conventional beliefs about cultural dimensions and their sway over workspace preferences. The outcomes, especially concerning Germany and Turkey, offer counterintuitive insights.

Practical or social implications – By discerning these intricate preferences, international corporations stand to benefit in crafting culturally attuned workspaces. This can foster a sense of well-being and possibly augment productivity. Moreover, it nudges us to re-examine cultural dynamics beyond the standard frameworks.

Type of paper – Full research paper

KEYWORDS

Work Environment, Workplace Management, Cultural Values, Equality.

INTRODUCTION

In an increasingly globalized setting, factors like migration, dwindling birth rates, and a scarcity of skilled workers present industry challenges. The rising demand for skilled labor in Europe and the influx of young professionals to Asia could jeopardize European economies. Countries like Singapore and Japan

[1] Bauhaus-Universität Weimar, BuiltEnvironment-Management-Institute, Thomas.vogl@uni-weimar.de
[2] Prague University of Economics and Business, Center for Workplace Research

are drawing global professionals despite linguistic hurdles (Hof, 2018). Hence, the acclimatization of employees to different cultural atmospheres becomes critical.
Multinational firms need to ensure a diverse workforce's engagement and satisfaction. This entails reshaping work environments (Avramov, 2016). Expatriates, whether self-initiated or assigned, grapple with cultural nuances in their host countries (Arseneault, 2020). They are vulnerable to workplace bullying (Bergbom et al., 2015) and may encounter subpar health and work conditions (Bertotti et al., 2017).

Nevertheless, cultural adjustment support exists. A home-country support network proves advantageous (Yao et al., 2015). Personal attributes like cultural humility, language skills, and organizational support aid cultural transition (Ramirez et al., 2020). Work environments directly influence employee outcomes (Pfnür, 2011). Studies show a correlation between the work setting and worker productivity (Appel-Meulenbroek et al., 2013; Feige et al., 2013). Hence, designing workplaces in tune with cultural nuances is key (Francis, 2013). Corporate culture reflects shared employee traits (Plijter et al., 2014), while national culture embodies collective values (Bond and Smith, 2018).
This leads to the quandary of integrating cultural values into tactile workplace designs. There's a call for research on embedding cultural values in physical design to enhance satisfaction and health. Existing studies present varied connections between national culture and workplace specifics (Plijter et al., 2014), with newer insights focusing on cultural rather than layout attributes (Heeroma et al., 2017). The hypotheses are: (H1) office space preference is perceived to be influenced by a culture's collectivism or individualism, (H2a) cultures that avoid uncertainty prefer fixed hours, and (H2b) are less inclined towards trust-based timings. Building on these hypotheses, our research aims to address the following questions: (RQ1) How do various national cultures perceive to influence workplace design?; (RQ2) What is the link between these cultural values and work hour preferences?, and (RQ3) Which cultural dimensions significantly shape the workplace environment? To answer these, our literature review and survey of 121 knowledge workers from Germany and Turkey strive to decipher the role of cultural values in shaping perceptions of the physical working environment.

LITERATURE STUDY

The definition of national culture and its theories

Originating from the Latin "cultura" in Cicero's "Tusculanes", where it translates to 'Philosophy is the cultivation of soul' (Cicero and Bouhier, 1812), the term "culture" has evolved from mere cultivation to a complex definition in society. Tylor (1974) described it as encompassing knowledge, customs, and behaviors humans acquire in society. However, Boas (1995) contested his views due to the cultural evolutionism. Kroeber and Kluckhohn (1952) saw culture as patterns passed on by symbols, with Hofstede Geert (1991/1994) defining it as "the collective programming of the mind."

Hofstede's influential national culture model started with four dimensions: power distance, uncertainty avoidance, collectivism vs. individualism, and masculinity vs. femininity (Hofstede, 1980). This expanded to include long-term vs. short-term orientation (Hofstede and Bond, 1988) and ultimately indulgence vs. restraint (Hofstede, 2010). This work emphasizes five dimensions, excluding indulgence vs. restraints. Other theorists, like Schwartz (1999), offer different dimensions, and Inglehart (1997) highlights generational cultural changes. The Inglehart-Welzel world cultural map, updated in 2023, showcases global value shifts (World Value Survey, 2023).

Five key cultural dimensions distinguish societies: individualism, power distance, masculinity/femininity, uncertainty avoidance, and long-term orientation (Hofstede, 2001; Migliore, 2011). Understanding these dimensions is critical in the workplace as they influence productivity, employee satisfaction, and organizational reputation. Recognizing these factors helps foster a constructive work environment promoting innovation and collaboration.

Workplace factors

The environment-related workplace factors can be categorized into three levels, which interact with each other. These are the physical, functional, and psychological dimensions (Budie et al., 2019). All three comfort levels of the spatial working conditions influence the users as stressors or in terms of their resources and impact the employees' well-being, motivation, satisfaction, and performance (Janneck et al. 2021, Bauer et al., 2018). The physical workplace factors are primarily related to the users' physical reactions and body dimensions, taking into account basic human needs, such as measurable environmental influences, acoustics, room climate, etc. Functional comfort implies coordinating the work environment with the work activities to support them best (e.g., room occupancy, distance differences between workspaces, movement sequences, special areas, movement, functional, traffic areas, etc.). Psychological factors target users' individual and interpersonal needs (exchange, privacy, crowding, territoriality, sense of control, etc.) (Windlinger, 2014).

In the course of this work, only those factors are considered necessary to answer the hypothesis and relate to cultural dimensions. Consequently, the focus is on factors associated with the design of office spaces that are in line with the organizational goals (Suckley et al., 2018). In our research, we investigated several workplace factors that are relevant to the design of office spaces. We focused on functional and physical factors impacting employee productivity and well-being. The functional and physical factors we examined include ergonomics, work equipment, and safety/hygiene. We also looked at functional and psychological factors such as social interaction, communication, and recreation facilities. Additionally, we evaluated the physical aspects of the workplace, including acoustics, climate, lighting, and aesthetics. Finally, we looked at the functional aspect of office layout and location. Together, these factors provide a comprehensive understanding of the important design elements for creating an optimal and comfortable workplace environment.

Cultural values and their impact on the physical work environment

Taras et al. (2011) created a Process Model detailing how national culture influences workplace performance. National culture first impacts an employee's emotions, attitudes, and perceptions, which subsequently affects their behavior and job performance. Various studies exemplify this: Arseneault (2020) highlighted differences between Korea and Canada's cultural values affecting expatriates;

Ramirez et al. (2020) discussed how Nordic countries' low power distance shaped workplace culture in Mexican subsidiaries; Plijter et al. (2014) studied office layouts in Germany, the Netherlands, and Great Britain, relating them to cultural factors like uncertainty avoidance. Nenonen and Lindahl (2017) emphasized the Nordic countries' focus on interactive workplaces, while authors like Sian et al. (2020) and Rao (2012) explored non-European contexts such as Saudi Arabia's gendered workplaces and India's traditional architectural principles.

Plijter et al. (2014) are particularly pertinent for this research, comparing international companies in Germany, the Netherlands, and Great Britain. Their findings show that national culture and workplace factors mainly influence office space types, occupancy density, privacy, and functional areas. High power distance cultures lean towards hierarchical spatial differentiation, and individualistic cultures prefer separate offices. This study also refuted some connections between cultural dimensions and workplace factors while confirming the association of uncertainty avoidance with innovation tolerance. Given these insights, a deeper exploration of this subject is imperative.

RESEARCH METHOD AND DATA SOURCES

Germany and Turkey were selected for comparison due to their similar population sizes but differing religious backgrounds, resulting in contrasting cultural values, as confirmed by Hofstede's cultural dimensions. Figure 1, detailing Hofstede's scores, demonstrates these differences. With its individualistic score of 67, German society values self-actualization and direct communication. The focus is on individual needs, often leading to the preference for cellular offices (Asino and Giacuma, 2019).

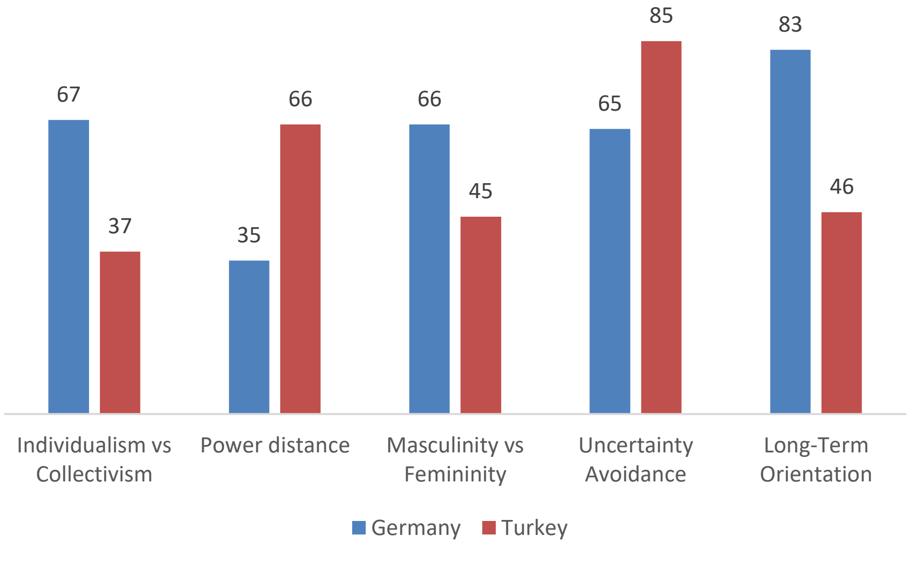

Figure 1 Comparison of selected countries of Hostede`s scores (Hofstede-insights, 2022).

Conversely, Turkey, with its collectivist score of 37, emphasizes group harmony, loyalty, and indirect communication in business environments (Hofstede Insights, 2022; Kasapoğlu, 2014; Çakmakçı et al., 2008). In terms of power dynamics, Germans prefer decentralized power and participative communication, while Turks lean towards centralized power, hierarchy, and autocratic leadership.

Cultural differences also manifest in their views on masculinity vs. femininity and uncertainty avoidance. Germany values performance, and systematic approaches, and thrives in long-term orientations, while Turkey emphasizes consensus, rule-following, and uses religious rituals to mitigate uncertainty (Hofstede Insights, 2022; Kasapoğlu, 2014; Lucia-Casademunt et al., 2018).

From July to November 2022, we collected data via an online questionnaire tailored to evaluate the influence of national culture on workplace factors. Whilst convenience sampling (e.g., Bryman and Bell, 2011) lacks clear generalizability of findings, the approach was most useful to leverage the sample as it is efficient and simple to implement within a survey (Bornstein et al., 2013). The survey targeted 42 construction and real estate companies in Germany and Turkey identified via desk research through email dissemination. In addition to this, the survey was shared on social media, emphasizing knowledge workers. Ensuring cultural relevance, it was offered in both German and Turkish languages. Initial drafts of the questions were discussed in multiple sessions with workplace specialists, and the questionnaire was piloted. After the collection, the raw data was independently analyzed by the author.

The questionnaire, segmented into various sections, gathered responses on employment status, educational background, workplace satisfaction, preferred working conditions, and the evolution of workplace preferences post-pandemic. The workplace preferences built the center of the survey and are based on a selection from relevant literature (e.g. Bergefurt et al., 2022) and discussions with workplace research specialists. Thereby, the initial question drafts underwent iterative refinement through discussions with workplace research specialists and a pilot run. In order to capture the overall workplace satisfaction, respondents were asked to evaluate their overall level of satisfaction with their working conditions by indicating their level of satisfaction by using a 5-point Likert scale ranging from "very dissatisfied" to "very satisfied". Moreover, the questionnaire probed the importance of the 15 workplace factors identified by indicating their importance using a 5-point Likert scale ranging from "not important at all" to "very important" as well as the preferred office type by asking the respondents, which of the provided floorplans they prefer (individual, combination, multi-person, multi-space, open-plan) and the preferred working hour model (fixed-, flexible and trust-based working time). Furthermore, the questionnaire probed the impact of COVID-19 restrictions regarding the working locations by asking the respondents to indicate the average percentage of monthly working time they spent in the building of the organization, at home, or in other third places before and after COVID-19.
Due to sample size constraints, we filtered out responses from certain groups, like students or those with lower education. Out of 121 valid responses, 69 hailed from Germany, while 52 were from Turkey. Predominantly, respondents were economic, legal, engineering, and architectural professionals. Germany, in particular, saw a heavy representation of economic and legal professionals at 55%, followed by engineers and architects at 13%. On average, respondents were 38 years old, with a gender breakdown of 52 females and 69 males.

RESULTS

The following section discussed the results of how cultural differences between Germany and Turkey influence workplace preferences and overall well-being at work. Figure 2 reveals comparable workplace satisfaction levels in Germany and Turkey. While no employees in either country reported extreme dissatisfaction, 18% in Turkey and 6% in Germany expressed dissatisfaction. Turkey had 46% satisfied respondents, with 14% very satisfied, compared to Germany's 52% satisfied and 10% very satisfied.

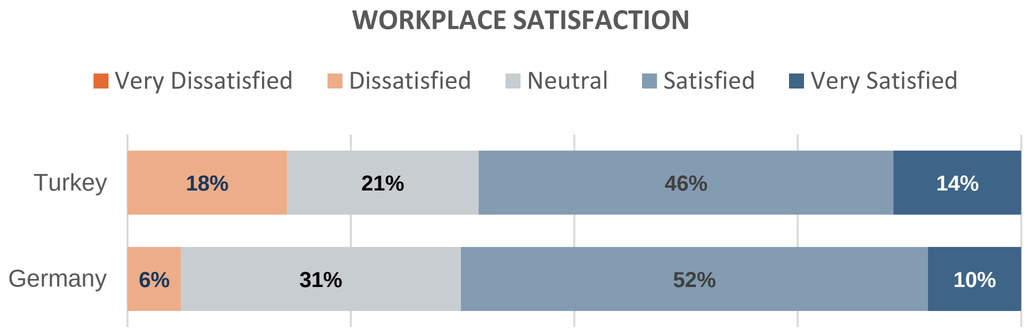

Figure 2 Comparison of Workplace Satisfaction.

Figure 3 contrasts working locations pre and post-Covid-19. Pre-pandemic, both countries predominantly worked from company premises (Germany 73%; Turkey 74%). Germany had 22% working from home and 5% from third places, while Turkey had 16% home workers and 10% at coworking spaces or cafes. Post-pandemic saw a dip in company premises work (Germany 47%; Turkey 49%) and a rise in home office (both 39%). The work habits significantly shifted during COVID-19, showing analogous changes in both nations' work locations.

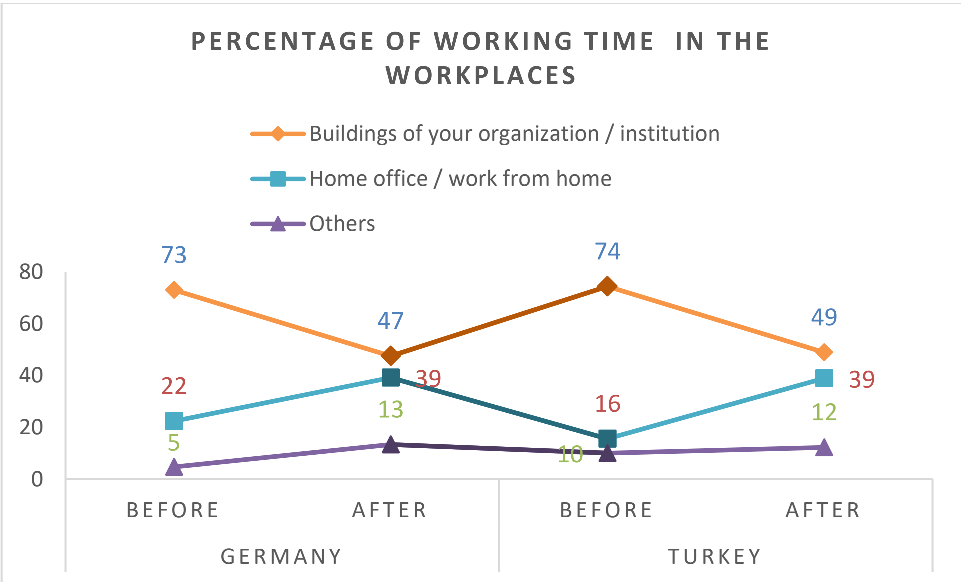

Figure 3 Comparison of working locations before and after the Covid-19 pandemic.

Figure 4 illustrates respondents' preferred office types. Germans largely preferred "mainly private" to "mainly open" office settings, whereas Turkish preferences spanned all five office types, with 18% favoring entirely private spaces.

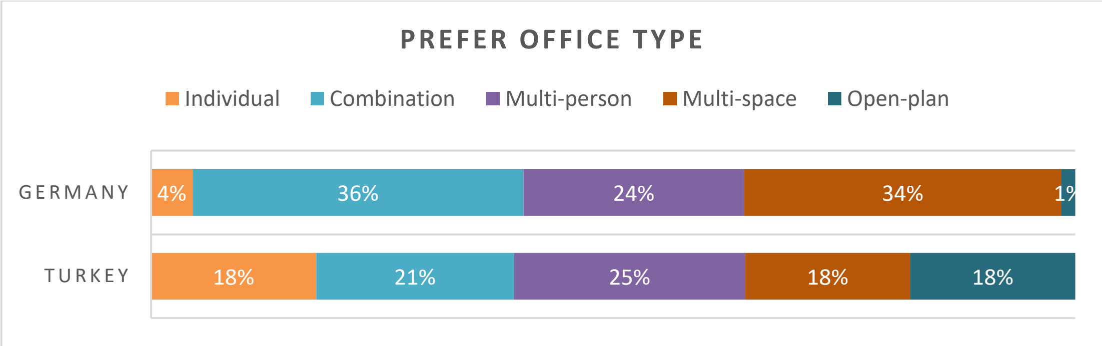

Figure 4 Comparison of preferred office types.

In Germany, the combination office (36%) with enclosed spaces and common areas is favored, as is the open multi-space office (34%). Conversely, Turkish workers lean towards multi-person offices or shared team rooms (25%). A stark contrast emerges in open-office preferences: just 1% in Germany versus 18% in Turkey.

Figure 5 compares preferred working hours. Over half of respondents in both countries prefer flexible hours. In Germany, 40% approve of trust-based hours, while only 9% favor fixed hours. With high uncertainty avoidance, Turkey showed an 18% preference for fixed and trust-based hours.

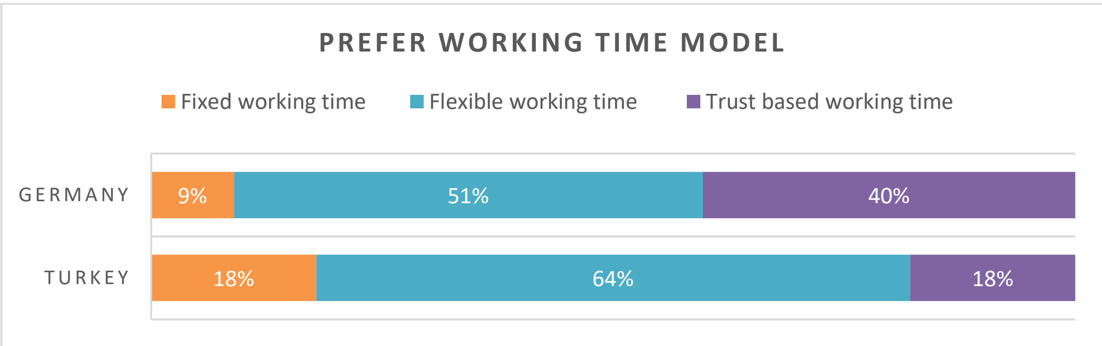

Figure 5 Comparison of preferred working hour model.

Figure 6 highlights workplace factors' importance. German respondents value external workplace factors like climate and acoustic comfort more than their Turkish counterparts. However, both cultures consider these factors significant for well-being.

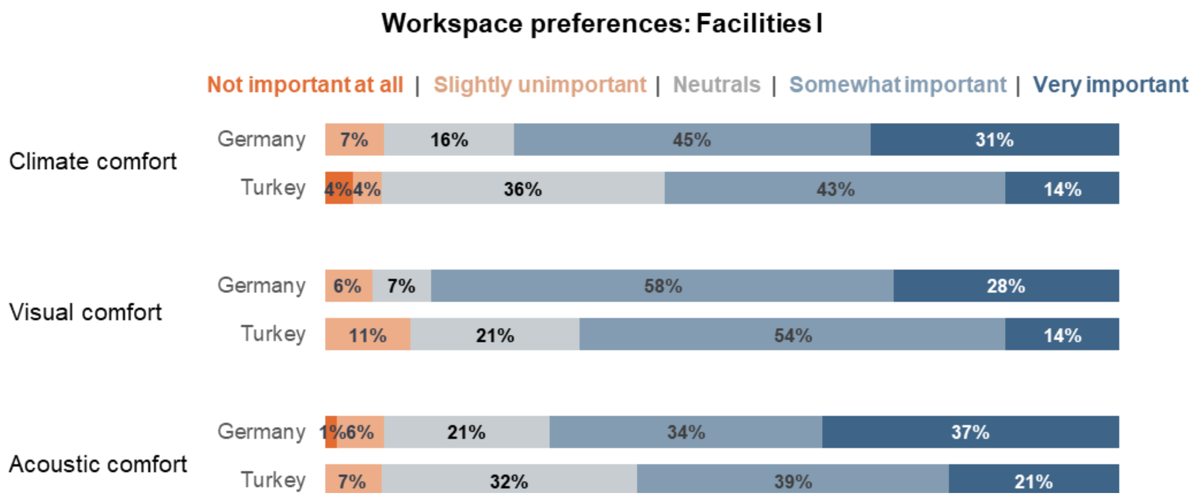

Figure 6 Preferences of physical workplace factors.

Figure 7 delves into workplace design preferences. Surprisingly, 78% of Turkish respondents prioritize spaces for solo concentration. Germans prioritize communication facilities (80%). Regarding cultural attributes, respondents were asked about traditions or religious practices facilities. Only 16% of Germans found this crucial, whereas in Turkey, 36% did, though 43% were neutral.

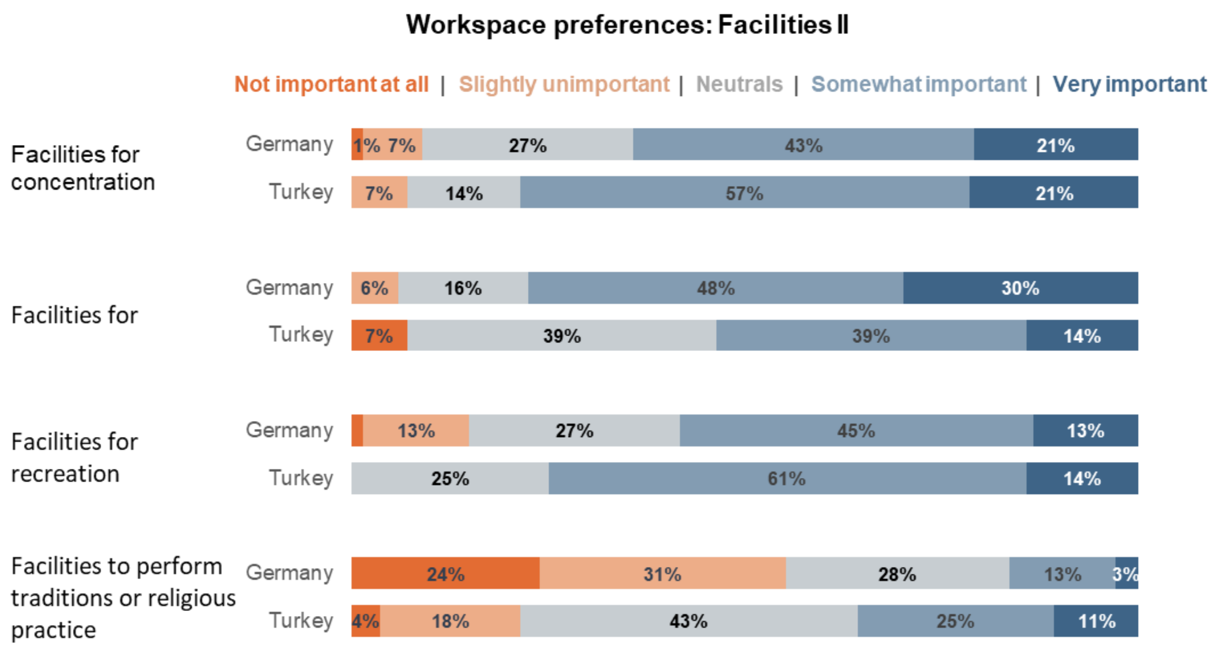

Figure 7 Workplace design preferences.

Figure 8 illustrates workplace service preferences. Office cleaning is paramount in both countries. Germans place less emphasis on safety/security (less than 50%), while 86% of Turkish respondents deem it crucial, likely due to high uncertainty avoidance. Significant differences can be observed regarding the safety or security services that were rated as somewhat to very important by less than half of the German participants. If we set the contrast; in Turkey workplace safety was rated as somewhat to very important by a total of 86 % of the respondents. Germans also rated other office services as somewhat to very important (46 %). In contrast, over half of Turkish respondents (64 %) considered such services somewhat important.

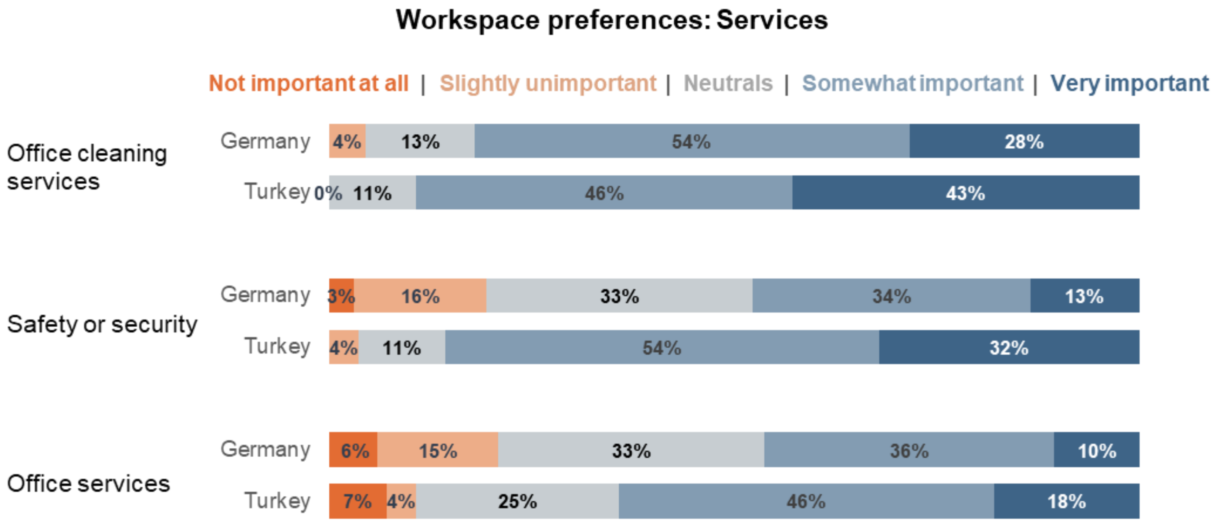

Figure 8 Workplace service preferences.

Figure 9 displays interior workplace design preferences. Both cultures prioritize ergonomic facilities and office location. For Turkish respondents, office location's prestige was especially important, suggesting status significance in high power distance cultures. Germans value healthy workplace conditions (88%), more than Turkish respondents (75%).

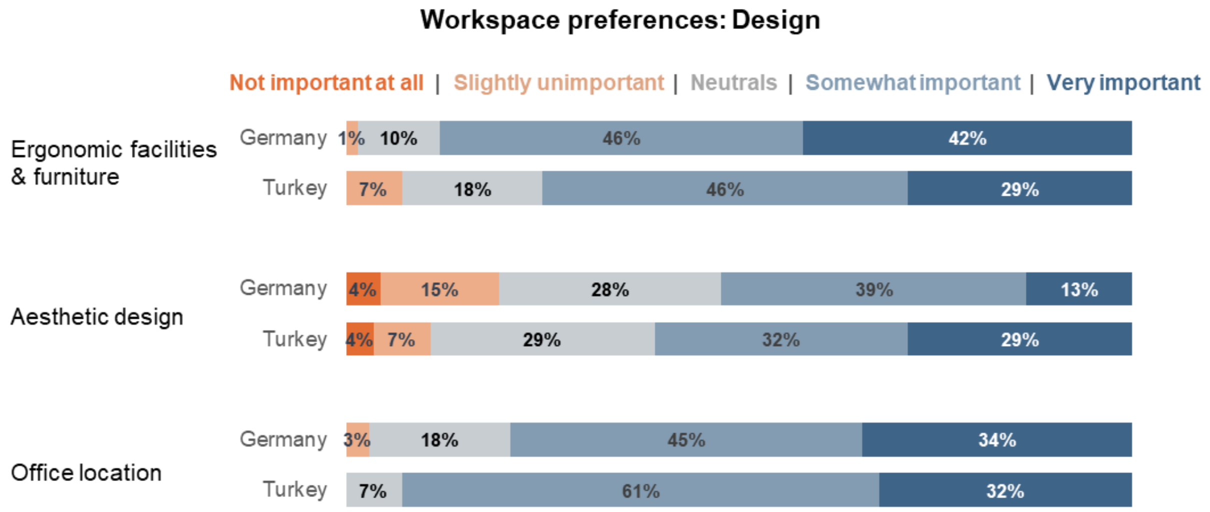

Figure 9 Workplace design preferences.

In summarizing the findings, there are notable disparities in workplace preferences between Germany and Turkey, possibly influenced by cultural nuances. The most pronounced difference lies in safety and security perceptions: in Turkey, this feature is highly valued, with 86% considering it paramount, while only 47% of Germans view it with similar importance. Additionally, facilities for communication, religious practices, and other external workplace factors further differentiate the workplace priorities of these two nations.

DISCUSSION

Our study uncovered nuanced perceptions regarding job satisfaction between Turkey and Germany. Turkey exhibited a slightly more negative outlook, which resonates with the findings of Statista's 2020 report, hinting at possible influences from Turkey's internal political landscape and its economic challenges. Both nations mirrored the global shift towards teleworking during the pandemic era, consistent with the literature (Pataki-Bittò and Kapusy, 2021; OECD, 2018).

However, the results diverged from our initial hypothesis (H1). While we anticipated that collectivist cultures like Turkey might favor multi-person offices and individualistic ones like Germany would gravitate towards single offices, the data suggested otherwise. Only 4% of German respondents exhibited a preference for individual offices, contrasting the 18% in Turkey. While these findings challenge the traditional assumptions (Plijter et al., 2014), they harmonize with some recent studies (Nenonen and Lindahl, 2017; Lai et al., 2022). This divergence might indicate evolving workplace trends and the interplay of multiple factors beyond cultural values alone. The preference among Turkish knowledge workers for shared team rooms or multi-person offices was noteworthy, supporting the idea of collectivist cultures valuing teamwork and interpersonal connections (Andreassi et al., 2014; Plijter et al., 2014).

Our initial hypothesis (H2a) suggested a possible link between high uncertainty avoidance nations like Turkey and a preference for fixed working hours. While the data showed patterns consistent with this hypothesis, we caution against making broad claims. German respondents indeed seemed to prioritize comfort in different aspects more than their Turkish counterparts, whereas the Turkish participants emphasized social spaces, possibly indicating a cultural inclination towards close working relationships. The greater value German respondents placed on communication spaces and the heightened emphasis on workplace safety among Turkish respondents offers intriguing areas for further exploration. Similarly, observations on preferences for other office services, religious practice spaces, ergonomics, and aesthetics provide rich grounds for additional in-depth investigations.

CONCLUSION, LIMITATIONS, AND IMPLICATIONS FOR FUTURE RESEARCH

The research on cultural values and their link with the physical workplace is complex and marked by contradictory assumptions and findings in the literature. The literature review did not identify a universally optimal solution but established that cultural values affect workplace factors. Only one publication, Plijter et al. (2014), was found to be highly relevant to the aim of this paper. This may indicate a lack of attention to the topic and great research potential or that cultural theories are unsuitable for physical workplace design. However, this would contradict the statements of many authors who have noted the importance of national cultures in work environments. Most literature on this topic deals with intercultural conflict management, leadership, discrimination, bullying, or human resource management, with little focus on the physical workplace environment.

This paper has revealed that cultural differences are perceived to influence workplace preferences and the need to incorporate national values into workplace design. Some argue that the work environment should align with the goals of an organization, while others argue that employee well-being and productivity depend on their individual needs and tasks. The results suggest that national cultures are perceived to influence workplace design, but that global scaling of workplace design is insufficient and requires a multifaceted consideration of different factors that influence employee performance and well-being. Culture can serve as an aid in planning and design, but not as the sole basis for it (Heeroma et al., 2017). Possible solutions include employee participation and involving local architects who can bring national needs into the design process. Further research can investigate the suitability of other cultural theories for design factors and a more detailed examination of the sample with regard to working sectors, age groups, and a wider range of countries.

It is important to approach the data with caution due to its inherent limitations. The restricted survey duration, a limited sample size, and challenges in differentiating sector-specific nuances pose potential constraints on the breadth of our findings. Further, the analytical approach primarily leans on frequency tables. We acknowledge the absence of significance testing which might have provided more conclusive insights. Moreover, individual variances in cultural values and the potential datedness of some cultural indices warrant mention. Hence, the observations and subsequent conclusions should be interpreted in light of these limitations. It's essential not to generalize or overstate cultural distinctions between Germany and Turkey based on this data alone. Yet, in spite of these limitations, the insights gleaned can be instrumental for multinational entities, especially in HR, Corporate Real Estate Management, and Workplace Management domains. This research stands to inform more culturally attuned office planning and design, especially in the contexts of Germany and Turkey.

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Building Automation and Control Systems: A Facility Manager's secret weapon?

Van Roosmale, S.[1,*], Vandenbogaerde, L.[1], Verbeke, S.[1,2], Audenaert, A.[1], Meysman J.[1]

ABSTRACT

Background and aim - This paper presents a perspective on the interaction between Building Automation and Control Systems (BACS) and facility management. BACS have the potential to improve energy efficiency and comfort, while assisting the facility management department. However, certain uncertainties hamper the mass implementation in office buildings.

Methodology - Relevant literature is analysed to provide a comprehensive overview – of the current state-of-the-art -, in addition to preliminary insights from interviews with facility managers, on which the authors viewpoint is based.

Results - Results from literature reviews indicate that BACS can support facility managers with strategic decision-making and finding a balance between energy efficiency and comfort levels. However, the efficacy of BACS implementation is strongly case dependant. Challenges with BACS, such as obsolescence and interoperability are found in literature and backed by interviews already performed. These challenges will be examined in the B-CLIC research.

Originality - To our knowledge, there is no previous research conducted on the benefits and challenges concerning facility management and BACS. The aim of B-CLIC in quantifying costs of smart building technologies over the life cycle is unique.

Practical or social implications - A future aim is to provide a holistic design view of LCCA and the energetic impacts of BACS. Facility Managers, Energy Service Companies (ESCos), BACS manufacturers, etc. could benefit from this because there is more certainty about their operation and costs in practice.

Type of paper – Viewpoint paper

KEYWORDS

Facility Management, FM, Building Automation and Control Systems, BACS, Smart buildings, energy performance, LCCA.

INTRODUCTION

Given that buildings are responsible for 30% of global final energy consumption, the need to improve their energy performance is evident across various building types (Delmastro, 2022). For instance in office buildings, where facility managers have a vital role in ensuring sustainable environments that offer optimal comfort to occupants. Traditional measures for reducing energy consumption of buildings include minimizing thermal transmission, increasing the efficiency of technical installations, installing

[1] Energy and Materials in Infrastructure and Buildings, University of Antwerp, Faculty of Applied Engineering, Groenenborgerlaan 171, 2020, Antwerp, Belgium
[2] Unit Smart Energy and Built Environment, VITO, Boeretang 200, 2400, Mol, Belgium
[*] Corresponding author. E-mail address: Sophie.vanRoosmale@uantwerpen.be

renewable energy sources or reducing energy loss through air leaks (Li *et al.*, 2013). A more recent development is the implementation of Building Automation and Control Systems (BACS) which could support a facility manager in the tasks to reduce operational energy consumption. EN 52120-1 describes BACS as a system comprising all products, software and engineering services for automatic control, monitoring, optimization for operation, human intervention and management to achieve energy-efficient, economical and safe operation of building services and is often referred to as a Building Management System (BMS) (NBN, 2022). BACS can ensure efficient control of heating, cooling, ventilation, domestic hot water, lighting and shading while maintaining or improving comfort. These systems typically comprise hardware components, i.e., sensors, actuators, interfaces, servers and controllers, and communication protocols, i.e., BACnet, Modbus and LONWORKS combined with software for energy management (Domingues *et al.*, 2016a). Thus, BACS can assist a facility manager with making strategic decisions about the sustainability of a facility through all kinds of collected data regarding time-related energy consumption (Pun *et al.*, 2017a). Despite its significant potential, a BMS is a complex system, and components are susceptible to malfunctioning and security risks (Aste *et al.*, 2017; Graveto *et al.*, 2022). As a result, maintenance costs can become unforeseeably high and due to the rapidly evolving market, not all replacement parts remain available.

This paper will delve deeper into the benefits and risks of BACS for FM in office buildings. After the state-of-the-art concerning the potential of BACS for FM and energy savings, the viewpoint of the authors will be provided about what changes are necessary to unleash the full potential of BACS.

LITERATURE STUDY

Benefits and challenges of BACS for a facility manager

Historically, facility management and maintenance were regarded as ancillary expenses. However, research from Pun et al. (2017) found that non-optimal maintenance planning can lead to 18-30% of additional maintenance costs . BACS, a more recent development, has potential benefits in supporting facility managers to realise a cost effective and more sustainable way of maintaining buildings (Atkin and Bildsten, 2017; Osma et al., 2015; Pun et al., 2017).

BACS have many benefits for facility managers, such as support with data-driven strategic decision-making in function of increasing the life expectancy of the building (Domingues et al., 2016). BACS collect and analyse large amounts of physical data, e.g., temperature, daylight illuminance and air quality. This data is combined with historical data, occupant behaviour, project information, weather data, etc. to support the facility manager with selecting the correct setpoints and creating a better maintenance plan to improve the energy consumption, the comfort level for occupants and the life cycle of the different components of BACS. This supports the facility manager to combine contrasting goals, such as an ideal comfort level and optimal energy efficiency (Domingues et al., 2016; Ramsauer et al., 2022). A well-equipped BACS assists in reducing operational costs through preventive maintenance and condition-based maintenance. An even more efficient form of maintenance could be possible by adding Fault Detection and Diagnostics to BACS, resulting in the 'predictive maintenance'. This can lead to savings of

5-30% according to Dong et al. (2014). With predictive maintenance, it is possible to avoid defects and breakdowns in for example HVAC, lighting and blinds, because it notifies the facility manager in real time when and where maintenance is needed based on anomalies in the data. These anomalies are detected by comparing current data to historical data. If a facility manager responds adequately to the alarms of BACS with Fault Detection and Diagnostics when it detects an upcoming defect, possible breakdowns of the system can be avoided, leading to a better efficiency of the organisation in the building and a higher comfort level for the building occupants. In addition, it improves the sustainability of a building by extending the service life of materials and installations, this results in less waste being produced.

However, predictive maintenance requires a higher initial investment in BACS relative to a reactive maintenance approach. In addition, predictive maintenance is also a relatively new concept, which means it is still under development due to the complexity of the system to autonomously determine when and where maintenance is necessary (Bouabdallaoui et al., 2021). Other challenges in BACS are caused by rapid developments in technology, such as developments in the storage capabilities as well as the intelligence of BACS due to the ever-growing amount of collected data that needs to be analysed and stored. Another challenge is the risk of obsolescence, which means that parts of BACS are no longer supported for maintenance in their original state because there are no resources or the components are too expensive (Alelyani et al., 2019; Lomakin and, 2016). In addition, obstruction of interoperability can happen because future technological developments cannot be predicted and anticipated for. This results in a system dysfunction because of different components being unable to exchange information (Declerq, 2021). Also, vendor lock-in is a challenge because this means a facility manager becomes dependable on a specific vendor for updates, expansions and maintenance. When a facility manager wants to switch to another vendor, he will face problems relating to high costs and time loss (De Oliveira *et al.*, 2017). Further challenges are reliability, due to design/operational/manufacturer failures, which could lead to defects in BACS (Abdulmunem and Kharchenko, 2017), and the complexity of managing the BMS increases due to occupant influence on BACS, which could lead to conflicting goals in terms of comfort and energy efficiency and lastly security risks are happening more and more resulting in threats to the correct operation of BACS but also to privacy issues (Graveto et al., 2022; Li et al., 2023).

Energy saving potential

To assess the saving potential of BACS, EN 52120-1 proposes BAC efficiency factors which quantify savings based on fixed factors depending on the level of automation, divided by energy-consuming domain (NBN, 2022). The level of automation is divided into classes A to D, where D stands for a non-energy efficient BAC and class A corresponds to high-performance BACS. Class C is the reference class, corresponding to standard BAC functionalities. The saving factors for office buildings are shown in table 1 below.

Table 1 BAC efficiency factors for office buildings in EN 52120-1 (NBN, 2022).

		D	**C**	**B**	**A**
Overall	$f_{BAC,th}$	1.51	1	0.80	0.70
	$f_{BAC,el}$	1.10	1	0.94	0.89
Detailed	$f_{BAC,H}$	1.44	1	0.79	0.70
	$f_{BAC,C}$	1.57	1	0.80	0.57
	$f_{BAC,DHW}$	1.11	1	0.90	0.80
	$f_{BAC,L}$	1.10	1	0.85	0.72
	$f_{BAC,Aux}$	1.15	1	0.86	0.72

Besides these generic factors, various research is conducted on the saving potential of BACS through Building Energy Performance Simulations (BEPS) or field studies. Ahmed et al. (2015) introduced demand-controlled ventilation in a Finnish low-energy office building and achieved savings of 7-8% of total primary energy compared to a constant air volume system. Lowcay et al. (2020) found savings between 12% and 91% of lighting energy by implementing occupancy and daylighting control, depending on sensor resolution, occupancy, location and window-to-wall ratio. Lastly, Kang et al. (2015) proposed a control system for an automated shading system coupled with heating, cooling and lighting demand. The results showed a decrease in cooling and lighting energy of respectively 40.8% and 19.6%. Although the energy saving potential is clear, the energy savings are case-specific and depend on the level and specifications of the BACS in addition to the considered reference case. The generic saving factors of EN 52120-1 may not be accurate as influential parameters, i.e., climate, orientation and occupancy (behaviour) are neglected.

The range of duties of Facility Managers encompass monitoring, analysing and optimizing energy consumption (Lok et al., 2023; Shin et al., 2018). Therefore, it would be advantageous for Facility Managers to possess the ability to quantify the savings due to implementing BACS. The significance of BACS for FM will also intensify as the EPBD recast obliges that non-residential buildings should incorporate BACS when the effective rated output for heating systems or systems for combined space heating and ventilation is over 290 kW by 31 Dec 2025 (European Commission, 2018). In addition, the European Commission ensured the development of the Smart Readiness Indicator (SRI) which is a tool to rate the smartness of a building and raise awareness of the benefits of smart building technologies. This way, a long-term vision for increased energy efficiency, e.g., energy neutral by 2050 or earlier, can be drawn up at building or building stock level.

AUTHORS VIEWPOINT

BACS can emerge as a critical tool for optimizing energy efficiency and enhancing occupants' comfort in buildings. The implementation of BACS results in the creation of a substantial amount of data, which can provide facility managers with valuable insights into building operations, enabling them to identify areas for optimization. The potential downside of increased adoption of BACS in buildings is an unmanageable data flow, which could hinder the optimal utilization of BACS and become a burden for facility management. In order to extract useful insights, this data needs to be processed with a targeted approach. To this end, an increasing number of software providers are offering Integrated Workplace Management Systems (IWMS) and Energy Management Systems (EMS), which allow facility managers to aggregate and utilize BACS data more effectively, thus, exploiting the full potential of smart buildings. Min et al. (2016) state that an integrated management strategy focusing on proactive operation and maintenance is a key to success in reducing energy consumption. The utilization of IWMS has the potential to contribute significantly to the optimization of spatial organization and employee well-being, thereby enhancing the overall value proposition of an office edifice.

However, building owners of rented office spaces often fail to recognize the benefits of investing in energy-efficient measures, such as implementing an extensive energy management system, due to the absence of immediate financial benefits which results in a lack of funding for such projects. To address this issue, stricter requirements regarding the minimum energy management system need of buildings can be imposed. Furthermore, modern facility management is shifting towards strategic decision-making based on data, and as such, the responsibility for conducting maintenance activities is increasingly being outsourced to third-party service providers.

In addition, the authors consider that building automation manufacturers and service providers have a responsibility to take action to address certain challenges faced by the industry. These challenges include short product life cycles, inadequate interoperability, security concerns, and the issue of hardware or software obsolescence, which can erode trust in the industry. To combat these issues, the industry should focus on developing durable products that are optimized for operation by facility managers, while also being transparent about any additional costs.

From our perspective, the facility manager holds significant potential in advancing the sustainability goals of buildings and closing the performance gap during the building operation phase. This observation is corroborated by Curtis et al. (2017), who identified impediments in building ownership. The issue of building ownership is not always straightforward, and the influence of facility management on sustainability outcomes varies across contexts. Therefore, the availability of clear, objective, and quantifiable data is crucial to inform building owners about the potential return on investment. Curtis et al. highlight the absence of trusted, independent sources of information for energy conservation strategies, which is a challenge the B·CLIC research aims to address by providing manufacturer-independent and unbiased data. Improved cost estimations for facility management can also result from this effort, reducing the risk associated with maintenance contracts.

FUTURE RESEARCH

The Building Control Life Cycle Cost (B·CLIC) research project, originating from the University of Antwerp, endeavours to tackle the challenges posed by BACS, with the aim of providing facility management with informative data that facilitates a more expeditious adoption of BACS. The goals of B·CLIC include gaining a thorough understanding and provide decision support based on the energy efficiency and economic parameters of BACS, considering the complete life cycle of its components.

Notably, the researchers engaged in this project have not yet encountered any extensive research conducted on the life-cycle cost of BACS.

Currently, a review paper regarding the energy saving potential is published (Vandenbogaerde *et al.*, 2023). This paper concludes that the energy benefits of BACS are often unclear, and that current research mainly presumes an oversimplified reference case which leads to overestimations in energy saving potential. The review points out that influential parameters, i.e., climate, occupancy, occupancy behaviour and pre-set setpoints, affecting energy efficiency are often neglected in the BAC factor method. In addition, the paper compares the methodology of field studies to Building Energy Performance Simulations (BEPS), BEPS seems to be suitable for testing several combinations but strongly depend on the level of detail of the input parameters. Interviews and informal discussions with facility managers will occur where abovementioned challenges and uncertainties will be discussed.
This paper also references certain conclusions drawn from the other review paper, such as challenges with obsolescence, complexity, vendor lock-in and in a second review paper (van Roosmale et al., under review), critically examines the benefits and uncertainties of BACS for facility managers operability.
The energy saving potential will be assessed through Building Energy Performance Simulations (BEPS) where a greater level of detail can be achieved. These methods will be tested on case studies of office buildings containing BACS, after which the potential of BACS can be determined by defining a reference model with manual control and fixed setpoints.

To gather data on BACS costs and maintenance, a survey has been sent to facility managers, encompassing quantitative and qualitative aspects about BACS implemented in their buildings. The survey inquiries about automation types implemented, software and vendors used, service contracts and associated costs, energy consumption, component end of life, and facility managers' experience with BACS. Currently, the responses are being processed. Subsequently, in-depth interviews with facility managers will be conducted for further qualitative insights. The survey data will be analysed to draw conclusions on current practices with BACS, component life cycle, and maintenance costs. This information will inform a model to estimate the functional life expectancy of BACS components, taking into account maintenance and reliability aspects.

Next, the energy-saving potential results of BACS will be integrated with the maintenance and reliability model to determine the cost efficiency of different BACS strategies using Life Cycle Cost (LCC) analysis. This will aid in early design decisions for office buildings, including initial investment in BACS, operational costs for maintenance, software and energy consumption, costs for component repairs or replacement, and overall benefits achieved through implementation.

CONCLUSIONS

The Viewpoint paper draws attention to the critical role that Building Automation and Control Systems (BACS) play in optimizing energy efficiency and comfort levels in office buildings. The study examines the various challenges associated with BACS implementation, including reliability, maintenance, service life, and obsolescence, which can significantly impact LCC analysis.

Despite these challenges, the paper concludes that BACS offer tremendous potential benefits to facility managers. By reducing operational costs, increasing energy efficiency, and improving comfort levels, BACS can improve the bottom line for businesses while also contributing to a more sustainable future. However, the study also highlights the need for addressing the challenges of BACS implementation to ensure their effective adoption.

B-CLIC will provide insights into the challenges and potential benefits of BACS implementation, offering guidance to facility managers, ESCOs, BACS manufacturers, and other stakeholders on making informed decisions. This can enhance BACS adoption and effectiveness in achieving sustainable building operations.

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Carbon footprint of services – findings from German non-medical hospital processes

Andrea Pelzeter[1], Heike Prüße[2], Silke Bustamante[3], Franziska Ihle[4], and Martina Martinovic[5]

ABSTRACT

Background and aim – Non-medical processes in hospitals are part of the upstream and downstream supply (scope 3 emissions) according to Greenhouse Gas Protocol. Although these processes contribute significantly to carbon emissions, they are hardly researched. Hospitals need to measure the carbon footprint of these processes in an appropriate way. The aim of this research is to present a calculation model for the carbon impact of a service using an exemplary non-medical hospital process. The authors present the method itself as well as its advantages and challenges.

Methods – The carbon impact for an exemplary service is calculated by a bottom-up method taking specifics of products and processes into account. The used model distinguishes between emissions from operating equipment, consumables, transports of process-employees and aspects of service-related management.

Results – The presented approach offers detailed results for the exemplary process including emission drivers, thereby enabling suitable change processes. The "sterile processing" has a mean average of 8.79 kg CO2e per functional unit/year. Drivers are especially consumables. To reduce the effort of the bottom-up method and to reinforce comparability of the results, there should be more guidelines for processes in the specific sector.

Originality – The research uses the bottom-up procedure for carbon footprint calculation of services and further develops that in the field of non-medical processes of hospitals.

Practical implications – The proposed method can be applied in the context of hospitals and beyond in order to identify emission friendly optimisation potentials of non-medical services.

Type of paper – Full technical paper

KEYWORDS

Carbon footprint of services, CO2, hospitals' non-medical processes, sterile processing.

INTRODUCTION AND LITERATURE STUDY

The health care sector is responsible for up to 4.4% of the world's carbon emissions. Especially hospitals are highly emitting in scope 3 including the purchased non-medical services (Karliner et al. 2019). Nevertheless, sustainability research in hospitals mainly takes into account the emissions of medical core processes (scope 1 und 2 according to the Greenhouse Gas Protocol) while calculations of carbon footprints of hospital's scope 3 with, for example, the non-medical processes are rare (Quitman et al.

[1] Berlin School of Economics and Law
[2] Berlin School of Economics and Law, contact: heike.pruesse@hwr-berlin.de
[3] Berlin School of Economics and Law
[4] Berlin School of Economics and Law
[5] Berlin School of Economics and Law

2021, Keller 2021). Non-medical processes like sterile processing, laundry or catering are considered as difficult to measure. First, because of the complexity and a lack of control over the processes, which are partly provided by external service companies. Moreover, because there are heterogeneous approaches for calculating process carbon footprints. Of course, there are well-accepted international standards like ISO 14067, which defines the CO2-Footprint (CFP) as the carbon dioxide emissions within the complete life cycle of a service (ISO 14067:2018). Ideally, life cycle assessment of processes is very precisely defined in terms of system boundaries and functional units (FU). For example, this takes place in Product Category Rules (PCR) according to ISO 14025:2006 „Environmental labels and declarations". However, the current state is that, within these settings, there are nevertheless heterogeneous approaches and methods in calculating carbon footprints for services.

Non-medical process emissions are often calculated by top down approaches like the environmentally-extended input-output analysis. This analysis combines financial transaction data for specific sectors with general emission factors (Klaaßen & Stoll 2021, World Resources Institute & World Business Council for Sustainable Development 2013). In this "top-down" method adapted to hospitals, services are often summarised as a compound item labelled "external services" and associated costs are multiplied by a general emission factor (ADEME 2020). For example, for (external) services in hospitals 90 t CO2e/Mio. € are generally calculated (from Environmental-Economic Accounting from German Federal Statistical Office according to Franke et al. 2022). Advantages of the method are manageable effort, common acceptance and that the results are providing a good overview. However, on the other hand, it can be seen as problematic when hospital-specific processes are framed as "other business services" because the use of general emission factors could end up in an underestimation of the contribution of non-medical services to the total carbon footprint of a hospital (Weisz et al. 2020). Moreover, such results are somewhat unspecific and without indications of drivers within the process and therefore not useful for monitoring.

Because of that, and moreover due to increasing reporting duties and stakeholder expectations, it is necessary to calculate the carbon dioxide equivalent (CO_2e) footprint of services in hospitals more detailed by a „bottom-up"-procedure or at least by hybrid models combining both techniques, which allow to identify potential drivers and discuss optimisations in more detail (Weisz et al. 2020). Process-based "bottom-up" analysis can take into account detailed carbon footprints for each used product and individual consumption data of the company (World Resources Institute & World Business Council for Sustainable Development 2013, Crawford 2008), as well as specifics of the process like transportation of the service employees and aspects of service-related management. The latter two aspects can have a serious influence on the total carbon footprint and should therefore be included into calculations (Pelzeter 2022).

There are several reasons why bottom-up approaches should be developed and tested for services: They are more accurate by taking into account specifics of products, processes and organisations. They facilitate the identification of specific emission drivers within the process and that enables suitable change processes including goal setting, design of measures and monitoring/evaluation. However, precondition for the increase in appliance of bottom-up-methods is harmonisation through guidelines (like "GEFMA 162-1 Carbon Management for Facility Services") or PCR according to international standards like ISO 14025. Because at the moment, there is no consensus about the correct definition of system boundaries and the adequate functional unit used to be able to compare process related footprints (Frischknecht 2020).

To sum up, there is a lack of appropriate process-based carbon footprint calculation in hospitals´ non-medical services. The objective of the research is to present a calculation model for the carbon impact for a service by using an exemplary non-medical hospital process. Advantages and limitations will be illustrated with an example. The process of sterile processing was chosen as an example because it is hospital specific but not classified as a medical core process. It is an example from the cleaning and hygiene services and other support services of a hospital.

Current state of calculation of service carbon footprint of sterile processing

Sterile processing generally concerns the central sterile supply of hospitals. It includes cleaning, disinfection, sterilisation and provision of medical products (small instruments) as well as the packaging within sterile barrier systems for the in-house distribution. So far there are only two PCRs that are related to hospital services: PCR – "Professional cleaning services for buildings" and PCR – "Service of providing washed and sterilized reusable surgical drapes and gowns used for patients and clinical staff" (EPD International AB 2018). The benchmark for the service focused on sterilisation of textiles has a range from 12.30 to 31.50 kg CO_2e for the functional unit of one kilogramme of drapes and gowns, during a year of service. It should be mentioned, that there are several very detailed aspects included in these EPDs, but they do not take into account transportation of the employees of the service and service-related management.

Further, there are a few studies concerning carbon footprints of sterile processing using bottom-up or hybrid models. A relevant study (Rizan et al. 2022) about the decontaminating (steam sterilization) and the packaging of surgical instruments uses a process-based carbon footprinting for most components and a cost-related model for the detergents (in accordance with the "Greenhouse Gas Accounting Sector Guidance for Pharmaceutical Products and Medical Devices"). The scope of analysis includes energy and materials required by the washer/ disinfector, steriliser, and sterile barrier system as well as the disposal of materials. Excluded are capital goods, hospital infrastructure, vehicular-based transportation between sterile processing and operating room as well as the production and disposal of surgical instruments. As a result, there are CO_2e summarised for direct and indirect greenhouse gas emissions (such as electricity, purchased goods, and waste) for several functional units e.g. the cycle of each decontamination machine or one surgical instrument (part of a set or individually wrapped and the kind of wrapping). Relevant optimisation potential of the study concerns the loading of the washing-disinfection-device as well as the sterile barrier systems.

A second relevant study (Friedericy et al. 2021) about the sterilisation packaging of surgical instruments in the operating room compares the life cycle assessment of single-use polypropylene packaging versus reusable aluminium-containers. The scope includes production phase, transport from production to hospitals, use-phase and end of life. The functional unit is sterile packaging of a standard instrument tray for 5,000 sterilisation cycles.

A third study (Lemonier et al. 2021) calculates the carbon footprint of the central sterile services and one sterilisation unit by a total cost-based model. The top-down approach includes consumables such as the consumed electricity, steam and water, waste (household and infectious clinical waste, wastewater treatment) as well as staff transport and equipment maintenance.

All studies offer no or no completely process-based approach. The scope definitions are different. The functional units are only partly likewise. In comparison to the CO_2e calculation model for services (according to GEFMA 162-1) the studies do not refer to aspects of service-related management. Only one study includes staff transportation.

To sum up, research should be done specifically and intensely for hospitals non-medical services. For that reason, the detailed analysis of carbon emissions of an exemplary service is shown in the following section.

RESEARCH METHOD

The applied methodology for CO_2e calculation for services builds on former research of the authors and develops it further (*Authors will be added after review process)*. It is mainly based on a guideline for the German Association for Facility Management e.V. (GEFMA). The procedures of collecting data, calculating and interpreting results were designed as followed.

Practice orientated procedure for the CO_2e calculation model for services

The calculations presented here were conducted in a research project funded XXX called "XXX (*will be added after review process)*". As a practice orientated research project, the procedure involved several partners from different sectors such as health care (hospitals), service providers and associations into the data collection with the following steps:

1. In a process mapping, experts from hospitals and service providers and the scientific project team defined the system boundaries of the process and listed equipment and operating consumables that are to be regarded as a standard for the process.
2. The scientific project team collected product carbon footprints for the listed products based on environmental product declarations, benchmarks from studies as well as prior own estimations.
3. Practice partners provided their primary, company-specific activity data, for example on the number of consumed materials, consumed energy and the numbers of employees working in the process.
4. The calculation was conducted according to GEFMA 162-1 with the result of a service carbon footprint, including plausibility checks between practice partners and the scientific team.

5. Results and CO_2e drivers were presented and discussed in a dialogue between the scientific team and the practice partners.

The data collection took place in 2021. For the steps 2-4, a calculation model based on GEFMA 162-1 was adapted for the project with the focus on hospital's non-medical processes.

CO_2e calculation model for services (according to GEFMA 162-1)

In 2020, the German Association for Facility Management e.V. (GEFMA) issued the GEFMA 162-1 guideline entitled "Carbon Management for Facility Services". The guideline provides information on how to estimate CO_2e emissions in facility services. The methodology in GEFMA 162-1 is based on the principles of ISO 14040ff. It also provides information on the allocation of emissions from four modules: operating equipment (for example devices, work wear), operating consumables (for example consumables, energy/ electricity, water), transportation (of employees or material) and service-related management (regarding office space, mobility, office equipment, paper consumption). GEFMA 162-1 suggests estimating the carbon footprint of a service per year.

Ideally, the product's carbon footprint includes emissions for production, transport to the place of use, use phase and end of life. This information can be found in Environmental Product Declarations (EPD). According to GEFMA 162, the product carbon footprint (for the product's complete lifecycle) is divided by the product's lifetime duration and added to the service carbon footprint (CFP) as an annual contribution. If the equipment is also used in other, separately considered services, a percentage for allocation to the service CFP is determined according to the usage share. The energy that may be required for the use of the equipment, e.g. electricity or fuel, is charged according to the annual consumption and allocated to the service under "operating consumables".

Transports are recorded for a regular movement of equipment to different locations as emissions of the respective service. This is based on the rules of EN 16258:2012 "Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)". In addition, the service-related mobility of employees is recorded under the transport category. Ideally, this includes the commute of the employees from home to the place of work.

The fourth area covers the overhead in terms of service-related management activities. For example, the activities of a service manager who coordinates the operative employees on site are considered to be service-related management activities. The general administration, including, for example, the human resources and controlling, is not integrated. The emissions from service-related management are calculated based on office and device use as well as mobility and in turn added to the service-related emissions pro rata - according to the proportion of hours spent on the service under consideration of the total hours of the service manager per year. The key figures determined in this way for each service can be analysed for carbon management with regard to drivers. Low-CO_2e alternatives for products or changes in processes can then be found and examined for the identified CO_2e drivers.

Data sources for CO_2e: key figures

There are different sources for CO_2e figures. If CO_2e footprints are available for the products in the form of Environmental Product Declarations (EPDs) from the manufacturers, precise CO_2e figures can be used. If this primary data is not available, benchmarks from studies can be used for these products or the emissions need to be estimated using own calculations. For these own estimations the project uses a simplified approach (Hottenroth et al. 2014). Aspects that are included in the estimations are lifetime duration, consumption of electrical power (for devices/ machines), operation hours/ year, product weight, type of materials and their percental share in the product according to weight, distance in kilometre with an assumption for different means of transportation in dependence of the length of the distance. Due to the uncertainty of the estimations, these are multiplied with an assumed surcharge of 50% (Pelzeter & Sigg 2019).

For the exemplary process "sterile processing", the calculation methodology explained above was applied. In 2021, data came from two German hospitals with a focus on general care, with about 300 and 600 planned beds.

Scope definition and system boundary of sterile processing

The sterile processing includes cleaning, disinfection, sterilisation and provision of medical products (small devices) including packaging, storage and in-house transport/ distribution. The scope of the analysis includes material inputs and activities that take place within the central sterile goods processing (see figure 1). This concerns mostly the treatment of small instruments. Excluded from the examination are large devices/endoscopy, as these are usually cleaned as part of the core medical process directly in the functional area (operation room) by using wipe disinfection or ultra-violet radiation. The product carbon footprints of the medical instruments themselves (e.g. surgical scissors) are not part of the scope of investigation of sterile processing, because they belong to the medical core processes. Included in the scope are exclusively those products (operating equipment and consumables) that are necessarily used during the process of sterile processing itself.

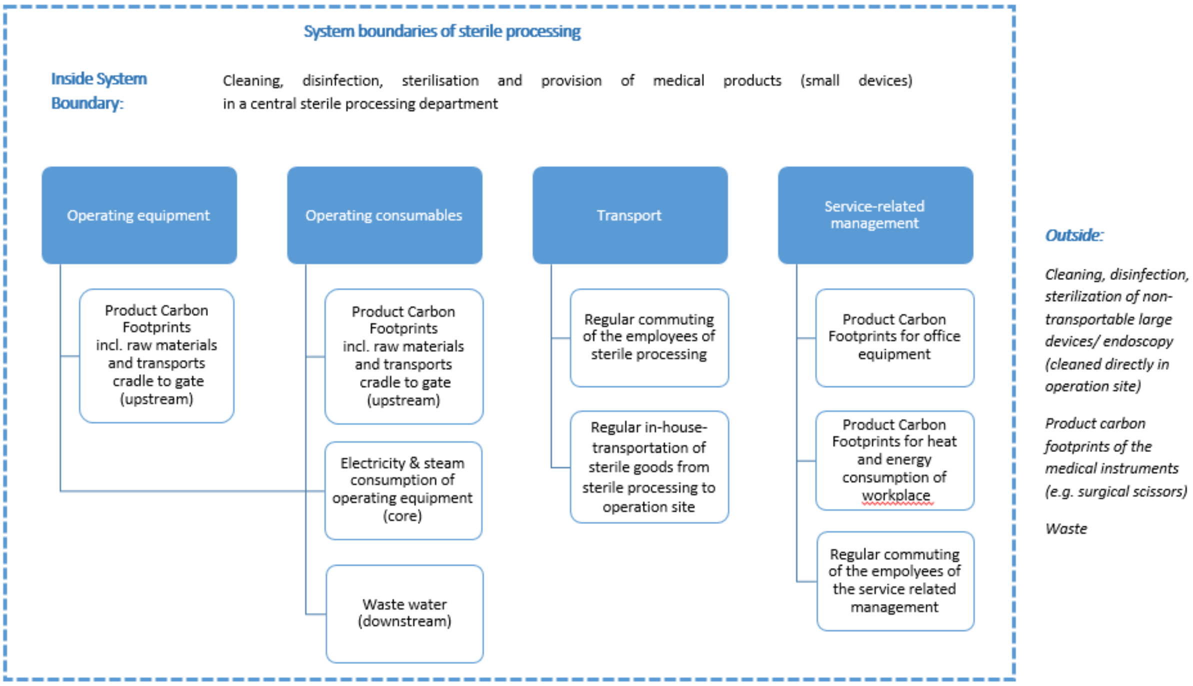

Figure 1 System boundaries of sterile processing.

The detailed list of products for calculating the service carbon footprint of sterile processing within the four modules of operating equipment, operating consumables, service-related management/ overhead and transportation can be found in table 1.

Table 1 List of products for calculating the service carbon footprint of sterile processing.

Module	Products (standard list, products may vary in different cases)
Operating equipment	Washing disinfection device, (steam) sterilisers, sieves, sterile goods container, transport trolley, automatic dosing machine, ultrasonic bath, LED light, magnifying glass, compressed air pistol, label printer, printer, standard PC, handheld scanner with cable, bag sealer, test device, worktable, working clothes - gloves (special reusable), work wear, working shoes

Operating consumables	Consumables: control indicators, fleece, foil bags, working clothes - eye visor (disposable), apron (disposable), face mask (disposable), thick household gloves (disposable), thin gloves (disposable) Around 15 cleaning agents, e.g. surface disinfectant, surface cleaner, disinfectant cleaner, special cleaner (instruments), special cleaners for washing disinfection device, special cleaners for ultrasonic baths, alkaline detergent, rinse aid, basic cleaner Energy consumption: For washing disinfection device, (steam) sterilisers, dosing equipment for cleaning agents/ process chemicals, ultrasonic bath Steam consumption: For washing disinfection device, (steam) sterilisers Waste water: For washing disinfection device, (steam) sterilisers, ultrasonic bath
Service-related management/ overhead	For employees who perform service-related work (e.g. administrative tasks to manage the service) proportionately (by an allocation formula) according to their working hours for the service-related management: Office equipment including personal computer, monitor, printer, smartphone, tablet, paper; by allocation formula Energy consumables for workspace; by allocation formula Regular transportation of the employees of the service-related management of the sterile processing including mode of transport, distance of commute, with a certain frequency per annum; by allocation formula
Transportation	Regular transportation of the employees of sterile processing including mode of transport, distance of commute, with a certain frequency per annum. Regular transportation of sterile goods between central sterile department and hospital department, including mode of transport, distance, weight of sterile goods container & transport trolley, with a certain frequency per annum. Upstream transport of goods is usually included in the particular product carbon footprint within the module groups “operating equipment” and “operating consumables”

Data sources of emission factors in sterile processing

For most devices, an estimation had to be made. Regarding the “operating equipment”, in case of the two hospital examples, the main twelve to thirteen devices had to be estimated and for five to six devices, an existing carbon footprint could be used. While for standard equipment, like desks or standard pc, benchmarks can be found, for specialised big devices, like the washing disinfection devices or sterilisers, there were no robust data available. Requests to manufacturers remained open. For “operating consumables”, there are more data sources available: For cleaning agents, an Environmental Product Declaration (EPD International AB 2022) within the group of PCR for detergents and washing preparations could be used. For the energy consumption, the German electricity mix (UBA 2020) is applied and for the steam consumption, an estimate was made. For employee “transports”, factors come from "TREMOD" (Transport Emission Model) which maps motorised traffic in Germany in terms of e.g. vehicle performance, energy consumption and the associated greenhouse gas emissions (ifeu 2020). For “service-related management”, there are some benchmarks for office equipment like standard pc, smartphone, printer and paper. Emission factors for consumables for the office room like heating and electricity came from the German Federal Environment Agency (UBA 2020).

RESULTS

The results of the calculation of the service carbon footprint are presented per functional unit. The functional unit of the service “sterile processing” is a sterile supply unit. The results per functional unit range from 6.15 kg CO_2e to 11.42 kg CO_2e. The mean average results in 8.79 kg CO_2e per sterile supply unit and per year. The results are shown in table 2.

Table 2 Results of the service carbon footprint of sterile processing in kg CO_2e.

	Hospital A		Hospital B	
	total	relative	total	relative
CFP Operating equipment	8,232 kg	9.6 %	13,080 kg	7.7 %
CFP Operating consumables	74,291 kg	86.4 %	143,889 kg	84.5 %
CFP Service-related management	241 kg	0.3 %	1,678 kg	1.0 %
CFP Transportation	3,223 kg	3.7 %	11,572 kg	6.8 %
CFP Service total	85,987 kg		170,219 kg	
Result per functional unit (FU)	11.42 kg CO_2e per FU		6.15 kg CO_2e per FU	
Sterile supply units (SSU)	7,532 SSU		27,690 SSU	

Optimisation potential

The results of the calculated service carbon footprints build the foundation for analysing where the drivers for carbon emissions within each process originate in. First, the level of the modules is scanned for the area with the highest CO_2e emissions. Through calculating the carbon footprints bottom-up, it is possible to determine exactly which products, consumables or other drivers are the main cause of the CO_2e emissions within the system boundaries. For both hospitals, the main driver are the “operating consumables” with 86% resp. 85%. The drivers within “operating consumables” are for both services mainly the electronic devices (see table 3).

Table 3 Drivers of CO_2e emissions within “operating consumables”.

Sterile processing – Top drivers within “operating consumables”	
	total in kg CO_2e
Hospital A	
Electricity consumption washing disinfection devices	36,342 kg

Steam consumption washing disinfection devices	15,210 kg
Electricity consumption sterilisers	14,414 kg
Steam consumption sterilisers	4,663 kg
Fleece	1,106 kg
Hospital B	
Electricity consumption all electronically devices	62,208 kg
Steam consumption washing disinfection devices	55,923 kg
Steam consumption sterilisers	17,046 kg
Fleece	37,210 kg
Work clothes - apron (disposable)	4061 kg

Possible savings through switching to electricity from 100% renewable energies in "sterile processing" are for hospital A 47,621 kg CO_2e for operating consumables. That are 64% of emissions from operating consumables and 55% of the total emissions of the sterile processing of hospital A. Hospital B could save 58,348 kg CO_2e, which are 41% of operating consumables emissions and 34% of the total emissions of the sterile processing of hospital B.

While transformation towards renewable energy is a measure that is to be initiated and implemented by the company as a whole, there are some optimisation potentials that are very specific to the process. Drivers in this case are consumables such as fleece and non-reusable aprons. Fleece means a material in which the finished sterile goods are wrapped into and stored in containers until the next use. To reduce emissions coming from the single-use product, there are several optimisations considerable like changeover towards renewable raw materials or collecting the polypropylene-fleeces separately and providing them for recycling. In a similar way, more optimisation models could be calculated and parameters towards change such as aspects of hygiene, costs and workflow routines have to be considered.

In the results, staff transportation ranges from 3.7 to 6.8% in both hospitals, and service-related management from 0.3 to 1.0% of the service's total emissions. Considering for example a changed commuting behaviour by employees, there is an optimisation potential that should be discussed.

DISCUSSION AND CONCLUSIONS

There are several reasons, why top-down approaches are not sufficient to calculate the carbon footprint of a non-medical hospital service. Overall, they are too imprecise, not regarding specifics. In contrast to that, bottom-up methods offer a deep dive into processes, an identification of specific drivers and thus enable suitable change processes including objectives, measures, monitoring and evaluation of actual changes. There are more reporting duties to come concerning scope 3 and supply chains like The German Act on Corporate Due Diligence Obligations in Supply Chains (2023), so that hospitals take more responsibility for emissions, even for those from outsourced services.

Applied to the chosen exemplary process, the method used is showing exactly these aspects: There is a result that is very tailored to the process. Within the result of 8.79 kg CO2e per sterile supply unit and year the method enables the identification of specific drivers and the discussion of optimisation potentials. The main drivers are "operating consumables" (86% resp. 84% of the service's total CO_2e emissions) with electricity on the top, so that switching to renewable energy sources and increasing energy efficiency are main recommendations. Further, practice partners use data to discuss change potentials for optimisation through raw material alternatives for specific products (like fleeces sterile barrier systems). Here the authors' results are consistent with existing studies, which also see sterile barrier systems (fleece, packaging) as an optimisation approach. In connection with the sterile barrier systems, the practitioners of the project discuss other work routines and other cooperation e.g. with procurement or the disposal company.

The results for employee mobility within sterile processing appear small at first, with an impact of 3.7 to 6.8% of the total process emissions. However, employee mobility is often a crucial point for reducing emissions at the level of the entire organisation. By making proportionate commuting emissions visible for the concrete work unit, it concerns its managers and employees directly, and can therefore be a motivation to choose environmentally friendly modes of transport.

There are limitations of the bottom-up-approach, too. The exemplary process can illustrate these: A crucial disadvantage is the comparatively high effort of the method needing a huge amount of individual data and product emission figures. The bottom-up or hybrid calculations often have very different foci, scope definitions and functional units. For example, the staff transportation and emissions for service-related management are mostly excluded. Further, there are many similar but not identical products mapped in the process for each individual hospital. The situation of data sources for product emission figures is challenging, too. There are in fact some carbon footprints for standard products, but because of lacking information of manufactures, for the large and specific devices for mechanical decontamination used in the process, estimations had to be made. In comparison to the life cycle assessments for example in Environmental Product Declarations, these estimations are less complex and thus, some device carbon footprints are probably underestimated in this study.

In general, because of these reasons, it is still difficult to compare results of service carbon footprints. For better harmonisation, there should be more agreements about scopes and functional units for example through guidelines or PCR for specific processes in certain sectors.

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A Disaster Risk Management Decision Support System for Improved Organisational Resilience: The MEDiate Project

Jones, K.[1], Mulder, F.[2], Morga, M.[3], & Wanigarathna, N.[3]

ABSTRACT

Background and aim – The UN Framework Convention on Climate Change challenged policy and business decision-makers to better understand climate hazard risk and develop adaptation/mitigation interventions to manage risk and improve resilience. The MEDiate project is developing a scenario-based decision support tool to help local decision-makers (regional planners, business/critical infrastructure managers) understand the impacts that interacting and cascading climate hazards have on community and organisational resilience. The MEDiate decision support tool integrates climate and risk modelling into a management framework that allows community and business decision makers to develop and evaluate mitigation and adaptation strategies to improve regional and organisational resilience.

Methods / Methodology – The MEDiate project uses a 3-cycle participatory action research methodology that brings together researchers and end-users to codesign and codevelop the decision support tool. This paper focuses on the findings from the 1st participatory action research cycle.

Results – The paper presents the results from a series of structured interviews, open discussions and workshops held with end-user stakeholders to validate a conceptual cascading hazard and risk impact model and implementation framework. The paper discusses the challenges faced by facilities managers in developing the scenarios and evaluating different risk management strategies to enhance resilience to climate induced extreme weather events.

Originality – The paper extends the facilities management risk and resilience models used for single hazard impacts to include multi-hazard interactions and cascading impacts.

Practical or social implications – MEDiate provides a framework for improved business and community resilience to disaster events.

Type of paper – Full research paper.

KEYWORDS

Climate change, community resilience, organisational resilience, risk assessment, decision support system.

INTRODUCTION

The frequency and severity of extreme weather-related disaster events (e.g., heatwaves, intense rainfall, storms etc.) are increasing, as are their impact (e.g., economic, environmental, and human losses) on communities, infrastructures, and livelihoods (Actuarial Post, 2021; European Environment

[1] Anglia Ruskin University, keith.jones@aru.ac.uk
[2] University College, London
[3] Anglia Ruskin University

Agency, 2023). The UN Sendai Framework for Disaster Risk Reduction (UNDRR, 2015) sets 7 clear targets and 4 priority action areas to reduce losses associated with disaster events. The Sendai Framework challenges all stakeholders involved with managing disaster risk to better understand the multiple dimensions associated with disaster risk and effectively integrate this understanding into risk assessment and disaster management/resilience plans, including developing and implementing risk mitigation plans that enhance disaster preparedness and response and encourage a "build back better" approach to disaster recovery, rehabilitation, and reconstruction. The Sendai Framework also explicitly recognises the need for collaboration between stakeholders involved in disaster risk management, acknowledging that while states have the overall responsibility for reducing disaster risk, other stakeholders, including business organisations, need to integrate disaster risk management into business continuity plans. The MEDiate project is a three-year research project to develop a range of disaster risk reduction tools and models that can be integrated into a web-based decision-support system (DSS) and business framework to allow end users (e.g., local authorities, businesses etc.) to build past, present, and future scenarios to model the potential impact of multiple interacting natural hazards on community and organisational resilience. The MEDiate DSS will also support the identification and evaluation of potential mitigation and adaptation risk management actions to either reduce their vulnerabilities (from a physical, economic, and social systems perspective) and/or improve their collective resilience. This paper describes the MEDiate project and the participatory action research (PAR) being used to actively engage end-user stakeholders in the co-design and co-development of the web based DSS. The paper presents the results from the first phase of the PAR where regional authority stakeholders from 4 testbeds across Europe reviewed the theoretical model against multi-hazard interactions and cascading impacts that had affected their regions. The results have been integrated into an initial business framework that will guide the co-development of the specific risk and decision support tools and models that will form the basis of the MEDiate DSS. The paper reflects on the emerging business model from a facilities management perspective.

ORGANISATIONAL RESILIENCE AND DISASTER RISK MANAGEMENT

The UNDRR (2023)[1] defines resilience as 'the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management'. ISO 22316 (2017) defines organisational resilience as 'the ability of an organisation to absorb and adapt in a changing environment'.

Business organisations need to view resilience from both an engineering and a business perspective. The difference lies in the focus of the resilience assessment. Whereas the former focuses on assessing physical damage, the latter prioritizes the assessment of the disruption and recovery of the "flow of goods and services." (Dormady et. al., 2019). To enhance their resilience, business organisations must take action to prepare for, respond to, and recover from unforeseen disaster events, including the risk of multi-hazard interactions and cascading impacts. This should be done within a system-of-systems approach that integrates the resilience of organisations and communities. To achieve this, businesses

[1] https://www.undrr.org/terminology/resilience

must integrate their physical assets with their operational processes and wider relationships with their suppliers, customers, and users. To build organisational resilience, it is crucial to prepare for disaster events by creating disaster management plans, resilience plans, and business continuity plans. These plans are practical tools to help organisations better understand their vulnerability, exposure, and risks to disaster events. They outline the actions that organisations will take to prepare for, respond to, and recover from a disaster event, if it occurs. They encompass a range of strategies, policies, and action plans that help organisations understand the potential impact of a disaster event on their ability to achieve their key strategic objectives. They also help organisations identify the resources, such as physical, human, economic, and corporate resources, that will be available to manage the immediate impact of the disaster and expedite the return to normal operations as soon as possible (Morga et al., 2022). MEDiate will use the PAR methodology developed by Jones and Mulder (2021) in the TURNkey[1] project to develop disaster management and resilience plan use-cases for earthquake events. In MEDiate, the PAR methodology is being applied to the co-development of a range of interacting climate change induced hazards and cascading impact scenarios (in essence integrated use-cases across disaster events) to support a greater understanding of the impacts of disaster events on a region's physical assets and socio-economic losses. The scenarios will allow regional stakeholders (planners, business organisations and communities) to identify and evaluate adaptation and mitigation options that can be integrated into disaster management, business continuity and resilience plans to mitigate the losses and support business and community recovery.

PARTICIPATORY ACTION RESEARCH

PAR is a transdisciplinary research and development methodology that has been applied to sociotechnical contexts where context needs to be considered alongside scientific enquiry in the development of problem-solving technologies and in which research subjects are viewed as active participants in the research process, rather than objects to be studied (Lewin, 1947). In essence, PAR is a group research activity where solutions are planned (co-developed), implemented, monitored (observed) and refined (reflected upon) with those end-user stakeholders responsible for delivering change (Adelman, 1993). Furthermore, PAR is a cyclical process where action cycles are repeated until an acceptable solution is achieved (convergence) or the project is abandoned (divergence). In this way PAR examines holistically the interaction between technical and social systems, rather than treating them as independent, parallel systems (Ghaffarian, 2011). In focusing on the interaction between systems PAR delivers a rich narrative discourse (in MEDiate a series of scenarios), where context is not considered fixed but is defined dynamically across the study; it can vary as the study progresses and potential solutions are tested.

In MEDiate, 4 inter-disciplinary PAR teams (one team for each testbed: Austurbrú, Iceland; Essex County, UK; Nice, France; Oslo Commune, Norway) of researchers, practitioners and stakeholders are working together to design, test, and refine the MEDiate DSS from a technical, operational, and managerial perspective over 3 PAR cycles, lasting 30 months. Each PAR team meets regularly (monthly or two-monthly) throughout the project, to review progress and reflect on emerging results. In addition, ad-

[1] https://earthquake-turnkey.eu/

hoc interviews, workshops, questionnaire surveys and software simulations are held with stakeholder representatives in each testbed. The results from each PAR cycle are formally reviewed by all MEDiate partners, testbed leads, and an international advisory board, at the end of each cycle. Any changes to the basic conceptual model needed to address the emerging stakeholder needs are agreed upon and programmed into the following PAR cycle. In the final 6 months of the project, results from the 3rd PAR cycle will be summarised and presented to an international expert panel through a Delphi survey to identify the broader learning that can be extracted from the MEDiate project and reported as general guidance for those seeking to develop similar disaster risk management solutions. Adopting the PAR approach should ensure that research outputs are both intellectually rigorous and practicably useable by decision makers. The PAR methodology is shown diagrammatically in Appendix A.

RESULTS: VALIDATION OF THE MEDIATE FRAMEWORK MODEL

At the time of writing this paper, the MEDiate project is approximately 9 months into the 1st PAR cycle. The PAR teams have reviewed and validated the original MEDiate Framework Model with the primary end user stakeholders (i.e., the lead regional authorities in the 4 testbeds) and developed strategic, policy, and operational level design guidance for the development of the first iteration of the tools and models that will support the MEDiate DSS scenarios.

The MEDiate Framework Model

The MEDiate Framework Model (Figure 1) was developed following the project's kick-off meeting, which was attended by the 4 PAR teams, and through follow-up discussions with individual testbed leads over the first 6 months of the project. The MEDiate Framework Model is based on Cutter's Disaster Resilience of Place Model for understanding community resilience to natural disasters (Cutter et. al., 2008) which links the antecedent vulnerability and resilience of a location (e.g., a region) with the impact that a disaster event would have on the ability of the region to accommodate and respond to the disaster. Cutter's model recognised the importance that any coping measures (e.g., physical and socio-economic mitigation interventions) would have on translating the physical impacts of the disaster events into community impacts and in realising a community's absorptive capacity to respond to the impacts. Cutter's model was combined with risk and resilience models developed by the authors in previous research projects (Jones et. al., 2013; Morga et. al., 2022) that developed business level risk and resilience assessment frameworks to interpret disaster risk and evaluate potential risk mitigation and adaptation interventions (physical, operational, and organisational) to improve both organisational and community resilience (Jones, 2022). The MEDiate Framework Model is an extension of the risk and resilience models developed in these previous projects.

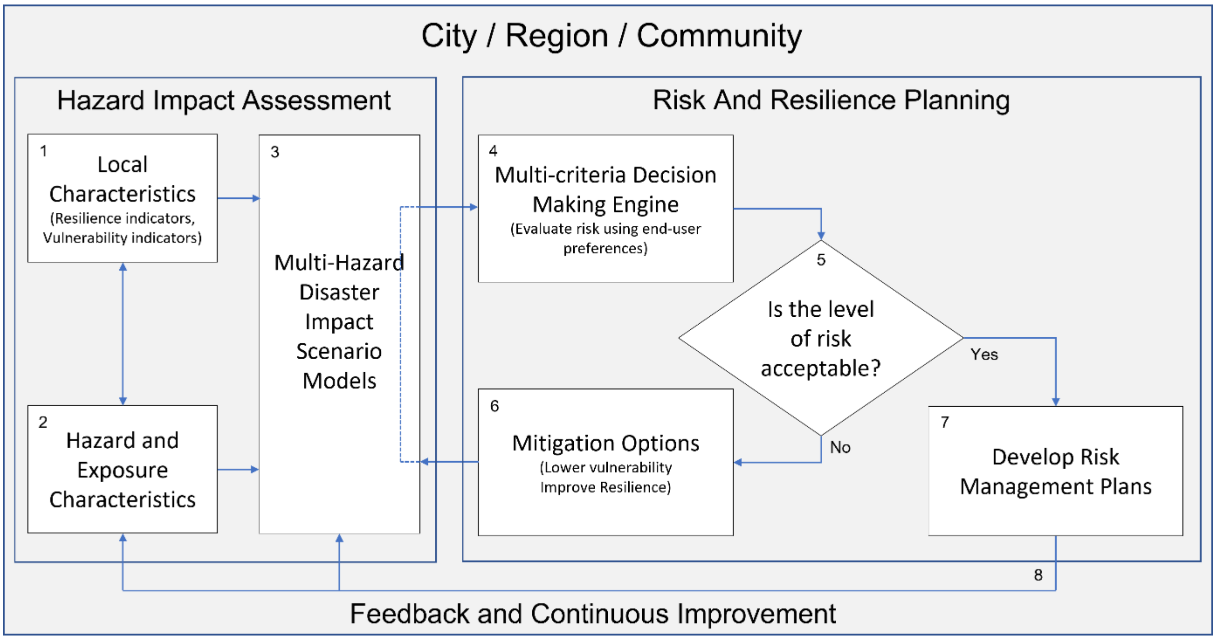

Figure 1 MEDiate Framework Model.

The MEDiate model describes an iterative process through which regional stakeholders can develop a range of multi-hazard disaster impact scenario models (3) that reflect their local characteristics (1) and their hazard and exposure characteristics (2). Local characteristics include natural, built environment and population topologies and economic activity profiles expressed as a series of physical, social, economic, institutional, infrastructure and community resilience and vulnerability metrics (metrics currently under development – see Table 1 for design guidance). Hazard, exposure, and vulnerability characteristics include past, current, and future disaster event scenarios and details of existing actions that would mitigate or exacerbate the impacts of the disaster event on the organisation and community. Local characteristics and hazard, exposure, and vulnerability characteristics feed into a range of multi-hazard scenario model templates that regional and organisational stakeholders can use to assess the short, medium, and long-term impacts that the hazard could have on organisational and community resilience. In essence this first stage of the MEDiate Framework Model is about better understanding the potential risks that different combinations of hazard will have on the region/organisation and providing an initial assessment of the capacity of the region/organisation to resist, absorb, and accommodate the risk.

The second stage of the MEDiate Framework Model uses the multi-hazard disaster scenarios to support the development and evaluation of mitigation interventions to manage the disaster risk and support improved resilience (6). Outputs, in the form of risk metrics feed a multi-criteria decision-making engine (4) that uses stakeholder preferences to evaluate risk appetite and support the development of risk mitigation options. Stakeholder preferences generally reflect the norms, rules, and expectations that dominate in their sector, their context specific learning over time, and/or community's shared values, beliefs, customs, and behaviours as well as moral regimes and local governance frameworks. If decision makers from the organisation or community deem the level of risk posed by a scenario to be unacceptable, then mitigation options can be identified to either improve resilience or lower vulnerability, and revised risk metrics can be calculated by the multi-hazard disaster scenario models and the impacts re-evaluated in the multi-criteria decision-making engine. This process is repeated until a range of mitigation options are identified where the residual risk is deemed acceptable (5) by the decision makers from the organisation or community, at which point risk management plans can be developed and enacted (7). Once enacted, feedback on the effectiveness of the risk management plans, either as a direct response of a hazard scenario being realised or through simulation of the hazard scenario in training exercises can be fed back into the hazard impact assessment module supporting feedback and continuous improvement (8) to the overall organisational or community resilience.

Testing the MEDiate Framework Model

The Framework Model was tested in each of the 4 testbeds. A questionnaire survey, followed by virtual interviews were conducted with the testbed lead organisations, as well as representatives from the scientific and technical work packages, to test the logic of the framework and identify its strategic, policy and operational level requirements (in the form of attributes that it must possess and issues that it must avoid). Participants were asked to rank the main hazards of concern in their testbed and reflect on how climate change would affect them. They were also asked to describe areas in their testbeds that were most exposed to hazards and give examples of assets and people that were the most vulnerable. In addition, they were asked to outline which local authorities, private companies and civil society groups were involved in managing resilience and disaster risk reduction in their testbed. They were asked to outline current approaches to disaster risk assessment and describe current disaster management support tools. Regarding the latter, they were asked to assess the strengths and weaknesses of current tools and describe what features they would like to see in future tools. The results from the questionnaire survey and interviews were reviewed at a one-day workshop of all MEDiate partners (37 participants drawn from research organisations, industry, and regional authorities). Following the workshop, the authors mapped the attributes and issues against the different stages in the MEDiate Framework Model to establish design guidance to inform the development of first operational (alpha) version of the MEDiate DSS. The results from the questionnaire survey, interviews, workshop, and mapping are summarised in Table 1.

Multi-hazard interactions and cascading impacts

In addition to testing the theoretical basis of the MEDiate Framework Model the questionnaires, interviews and workshop also explored stakeholders' understanding of interacting hazards and cascading impacts from hazard events. Stakeholders were asked to give examples from their testbeds of historic multi-hazard interactions and cascading impacts to help define the scenario building templates for the MEDiate DSS. The stakeholders provided examples for the following types of multi-hazard interactions and cascading impacts:

- **Interacting hazards** - where the primary hazard triggers a secondary hazard (or changes the probability of the secondary hazard). For example, where heavy rainfall could trigger landslides or flooding, or where heavy snowfall combined with changing temperatures could trigger avalanches. Failure to understand the relationship between the two events could lead to inappropriate responses from disaster risk managers.

- Compound hazards - when hazards coincide either spatially or temporally. For example, when a severe storm coincides with, or is closely followed by, a separate unrelated hazard event (e.g., an earthquake). Responding to several extreme events in quick succession would pose severe logistical challenges and require a high level of inter-organisational collaboration.
- Interconnected risks - when interdependencies between systems shape the risk. For example, in situations where power (e.g., hydroelectric generation) and water supplies are closely connected to rainfall and thus both are susceptible to drought; or where extreme rainfall can overwhelm a local drainage system resulting in flooding which in turn disrupts transportation systems. Failure to understand the connectivity could again result in inappropriate responses to either or both systems.

The challenge to the MEDiate DSS is to ensure that all of the above are considered when developing multi-hazard interaction and cascading impact scenarios for a region or area. At present, such integrated scenarios are largely missing from current disaster risk modelling.

DISCUSSION

The findings presented in Table 1 and the different risk scenarios were used to develop a set of end-user defined recommendations to inform the design and development of the MEDiate DSS. The recommendations, in the form of a high-level design brief, cover strategic, policy, and operational aspects of the disaster risk management cycle, and the potential impacts on community resilience.

Strategy-level considerations

At the strategic level, the MEDiate DSS must provide a long-term overview of geographically relevant hazard threats and interactions to inform the prevention and mitigation efforts of a range of decision-makers (from community groups and businesses, through regional disaster managers to national organisations). These strategic level outputs should inform end-users of future disaster risks to local, regional, and national resilience. At this level, the MEDiate DSS tools should provide decision-makers with easy to digest information that covers the entire area for which they are responsible. They should help decision-makers better prioritize risks based on their likely occurrence and on improved local disaster forecasting, identifying areas that will be most affected. To this end, outputs should be in the form of illustrative maps at different geographical scales and impact levels, with the ability for decision-makers to geo-locate assets (e.g., buildings, critical infrastructures, business organisations, community groups etc.) onto the maps and drill down through the underlying data sets to assess the level of disruption and losses to the assets, and estimated recovery time to return the assets to different levels of performance. Disruption and loss data should be presented in a format that assists interpretation and is compatible with existing tools used by the decision-maker when managing risk (e.g., emergency management, business continuity, and resilience plans).

Policy-level considerations

At the policy level, MEDiate DSS tools should inform future planning scenarios, both from an urban development and business perspective. The tools should allow the decision-maker to select a range of potential future scenarios (e.g., different climate change scenarios, different population demographics etc.) which the MEDiate DSS then uses to generate a series of future risk scenarios that reflect local context and circumstance rather than being based upon national level risk assessments. This effectively represents a bottom-up approach to risk management where local resilience assessments drive local adaptation and mitigation interventions that in turn inform national level resilience planning.

Operational-level considerations

At the operational level, MEDiate DSS tools should bring together and systematically process all the important data needed for risk monitoring. Currently this data is dispersed amongst different agencies and systems. In bringing the data together the tools should support decision-makers at different organisations (e.g., regional authority, critical infrastructure, businesses, etc.) make local decisions whilst ensuring coordination between the decision-makers (e.g., a decision to close roads could impact business logistics). As such, the tools need to be dynamic and reflect real-time circumstances during crisis situations, rather than being static/theoretical representations of an expected (modelled) reality. The tools need to provide information at the level of local detail needed to inform operational decision making; high level overview data alone is of limited use. In essence the tools need inform decision-makers of the implications of alternative decision (e.g., by showing interacting hazards and cascading impacts).

Community resilience

Community resilience relies upon effective management of disaster risks amongst all stakeholder groups in a region (UNDRR, 2015). To this end the MEDiate DSS has the potential to support effective disaster risk management providing that the interrelationships between the actions taken by each stakeholder group are recognised and integrated into a coordinated set of disaster risk management plans. Ali and Jones (2013) identified how a lack of communication between local businesses and the regional authority over the responsibility for providing building level flood protection before an expected flooding event led to businesses thinking they would receive help, when in fact such help was never anticipated by the regional authority. The impact of this lack of understanding not only resulted in many businesses flooding, but also resulted in a lack of confidence and trust between the stakeholders going forward. Jones and Ali (2013) also identified the need for different stakeholders within organisations to have a collective understanding of the vulnerability and resilience of their organisation to disaster events and identified the role that facilities managers need to play in developing this understanding. To avoid a similar situation occurring the MEDiate DSS must ensure that effective communication channels exist between stakeholders.

Table 1 Mapping of the critical attributes and issues for the mediate DSS against the conceptual framework.

	Stage (see Figure 1)							
Must Have Attributes	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*

Uses both local and national hazard information that is up-to-date and at an appropriate level of detail to identify impacts of multiple and cascading hazard threats on citizens and society today, and in the future.								
A mechanism for evaluating and prioritising hazard risks that reflects local stakeholders needs, is transparent in its application and includes the capacity to identify where an impact is likely to exceed the resources available to respond to the risk.								
Be accessible to (and widely used) by all those involved in disaster risk management at the national and local levels, including supporting and empowering collaboration between stakeholders at all stages of the disaster risk management cycle.								
Clear mandates (roles) and a good understanding of how effective the deployment of resources could be in managing the disaster risk.								
Support shared risk awareness amongst all stakeholders; probably based upon experience from recent past disaster events.								
Use easy to understand information in a language which is accessible to decision makers and professionals.								
A track record of being successful in a real-world situation; ideally validated against recent (past) disaster events.								
Outputs that can be easily integrated into wider policy documents or disaster/emergency management plans, including loss metrics that can be used to evaluate the effectiveness of alternative mitigation and adaptation interventions.								
Provide information in real time as a disaster situation unfolds, including supporting disaster managers direct relief as quickly as possible to the worst affected areas.								
Must Avoid Issues								
Short-term vision and a lack of coordination when managing (cascading) impacts								
Hazard maps which are based solely on desk-based studies; don't cover the whole of the region that the stakeholder is responsible for; or where key hazards are missing, or information is out-of-date. There must be a way to regularly update models with the latest national and local data.								
Delays in formalising risk documents and implementing risk preparedness and safety plans between different jurisdictions / organisational mandates.								
Confusion over roles and responsibilities between stakeholders when identifying risks and managing interventions, including suggesting mitigation and adaptation plans that are not within funding limits.								
Tools that are expensive to maintain by end-users, for example because they need to be updated regularly with local data that the end-users need to source.								
Tools that are rarely used (and thus easily forgotten) or that require input from specialist equipment or individuals that are not part of the stakeholder's normal personnel.								
Overloading operational decision-makers with 'high-level' information that doesn't directly support local operational disaster management decisions.								
Avoid wherever possible issuing false alarms about the potential impacts of an imminent disaster event.								

Aligned with the need to support effective risk communication between stakeholders, the MEDiate DSS needs to develop a series of risk metrics that are meaningful and applicable to local stakeholder organisations' context and circumstances. In particular risk metrics need to be compatible with risk assessment procedures and business continuity and disaster management plans. Whilst this statement might appear obvious, it will provide challenges to those developing a new range of risk metrics that can effectively model the different types of multi-hazard cascading impacts discussed in this paper. When developing cascading risk metrics, business and critical infrastructure organisations need to examine not only the direct impact that a hazard event (or combined hazard events) has on their organisation (e.g., physical damage to their built assets resulting in loss of production/service capacity) but also the indirect impacts that such hazards could have on the organisation's supply chain, logistics, and distribution networks.

Cascading hazard risk - challenges to facilities managers

Cascading hazard risk can be viewed as systemic risk that spreads within and across systems and sectors through the movement of people, goods, capital, and information within and across system boundaries, that, if not understood and effectively managed, can lead to catastrophic consequences and system collapse (Sillmann et. al., 2022). Addressing systemic risk requires actions that go beyond traditional approaches to risk management, where the impact of single risks on single systems are examined, to a holistic study of multiple hazard impacts on multiple systems. In particular, systemic risk models need to identify system interdependencies and underlying system vulnerabilities and their root causes from both physical and socio-economic perspectives (ibid). For this reason, risk managers need to explore how a response to a hazard impact in one part of a system (or systems) could affect positively or negatively other parts of the system, or other interrelated systems; this approach is fundamentally different to the conventional risk management approach and requires a deep understanding of the interrelationships between risks within and across systems (Cutter et. al., 2015). Further, in assessing systemic risk and its link to resilience business organisations need to understand the impact that climate change induced disaster events have on their organisation from a financial, human, built asset, social, and natural perspective. These so-called 5 capitals of organisational resilience provide the basis for organisations to develop systemic risk models using future disaster scenarios that consider not only the impacts of a disaster event on an individual capital but also explore the interrelationships between capitals over the short, medium, and long-term timescales (Denyer and Sutliff, 2021).

When assessing systemic climate change related risk, facilities managers need to explore both direct and indirect impacts of disaster events on their organisation's hard and soft facilities management (FM) systems (Jones, 2022) and the potential transfer of risk across systems. Take flooding as an example.
From a hard FM perspective, facilities managers would need to identify the direct impact that flooding would have on their built assets and the indirect impacts that this would have on business function (e.g., how physical damage to a building or equipment would affect their ability to deliver their primary business function). Facilities managers would also need to identify and evaluate potential adaptation and mitigation interventions that could either reduce the impacts (e.g., ensuring temporary flood protection measures could be implemented before the flood occurred) or support their organisation's recovery to an acceptable level of performance through flood resilience measures integrated into built asset management plans (e.g., relocating power distribution systems within buildings so that they are above the anticipated flood depth level).

From a soft FM perspective, facilities managers would need to identify the impact of flooding on their human resources (e.g., their in-house or outsourced FM personnel) to ensure that any mitigation interventions intended to reduce the vulnerability of their hard FM systems are not undermined by a lack of access to in-house or outsourced FM contractors or personnel. Again, consider the impact of flooding. In order to return their built assets to a functional state after a flood floodwater must be pumped out of their buildings, and the buildings dehumidified, cleaned, and possibly redecorated. Unless the organisation has previously contracted arrangements with specialist FM cleaning services that address flood recovery it is unlikely that those services will be available immediately following the flood event, given that many other business organisations and private citizens will also be looking for similar services. Further, even if specialist services are available, it is likely that the costs associated with procuring such services will be significantly greater than if a prearranged contract was in place (Dormady, et. al., 2019).

Finally, facilities managers are becoming increasingly involved in helping inform their organisation's environmental, social, and governance strategies and plans. From a climate change related systemic risk perspective, this requires facilities managers to identify potential risks to environmental and social systems, as well as to their organisation. Again, consider flooding. Facilities managers need, for example, to understand the risk of flood water on their site becoming contaminated (e.g., as a consequence of their chemical waste storage regime) and how this could pose a cascading risk to the local natural environment if contaminated flood water drains from their site. If such a risk exists, then facilities managers need to consider storing floodwater on site until it can be safely discharged. While such a mitigation would not immediately aid the organisation returning to functional performance, it would help manage any adverse publicity resulting from contamination to natural systems that, if unaddressed, could seriously damage the organisations reputation amongst the local community and its customer base.

CONCLUSIONS

Climate change is predicted to exacerbate the severity and frequency of extreme weather events, increasing the probability that business/critical infrastructure organisations and the wider community will face multi-hazard interactions and cascading impacts. The UN Sendai Framework has challenged policy and business decision-makers to better understand climate change related hazard risk and develop adaptation and mitigation interventions to manage the risks and improve resilience. The MEDiate project is developing a scenario-based decision support tool to help decision-makers, including facilities managers better understand the risk that multi-hazard interactions and cascading impacts could pose to their organisation/communities.

The results from the initial questionnaire survey, interviews and workshop confirmed the overall concept underpinning the MEDiate DSS and identified the critical attributes that the MEDiate DSS should possess, and the issues that it should avoid. In essence, the MEDiate DSS must adopt a long-term view of a range of single and multi-hazard threats to support a range of regional decision-makers in understanding the cascading impacts of disaster events on their organisation and wider community. Further, in supporting decision-makers the MEDiate DSS not only needs to provide decision-makers with an assessment of the physical impact and risks that the disaster events might have on their built assets, but also on their organisation's functional performance and overall business resilience. The MEDiate DSS tools should provide strategic decision makers with an easy to digest high-level overview of how multi-hazard interactions and cascading impacts might affect the entire area within their mandate in the long term to inform prevention and mitigation efforts. The MEDiate DSS should also provide policy-level decision makers with a range of comprehensive and detailed scenarios, informed by both high-level and local data, to inform resilient long-term planning and development. Finally, it should provide operational decision makers with detailed local information about multi-hazard interactions and cascading impacts to develop and integrate risk metrics into their risk assessment regimes. By providing information at different levels of aggregation (a high-level overview of a large area, detailed scenarios based on both high-level and local data, and detailed information about a local area) the MEDiate DSS can support the development of policies and operational plans to mitigate and manage hazard risks, today and into the future. In support of the latter, the MEDiate DSS must support the development of future risk scenarios against which adaptation and mitigation interventions can be evaluated, and where appropriate, integrated into disaster management and business continuity plans. The MEDiate DSS must avoid confusion over roles and responsibilities of different stakeholders before, during and after a disaster event. To this end, all stakeholders need to engage with the development and testing of the future multi-hazard interactions and cascading impacts to ensure they reflect the needs of the local community, business organisations and critical infrastructure providers.

To this end facilities managers whether employed in business organisations, by critical infrastructure providers or by public sector organisations, need to play an active role in developing multi-hazard and cascading risk models that reflect their needs and operating procedures. To support this, facilities managers need to develop a broad understanding of resilience and disaster risk management, and in particular of systemic risk modelling across internal organisation boundaries and wider system boundaries.

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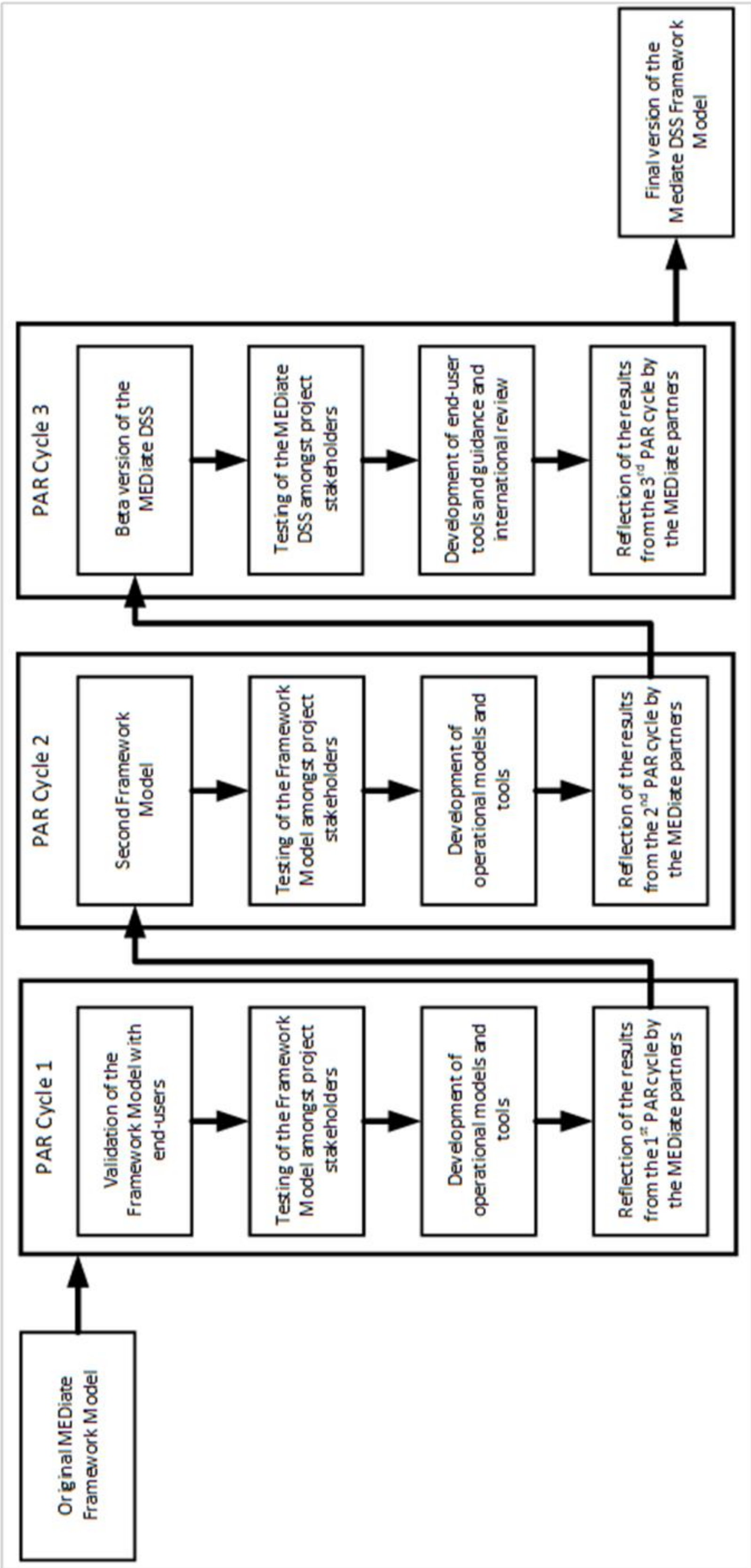
Appendix A The MEDiate PAR Model



The Role of the Management Plan in Residential Buildings and its Effects on Facility Management: The Case of Turkey

Harun Tanrıvermiş[1] and Esra Keskin[2]

ABSTRACT

Background and aim – The management plan regulates the management practice, the purpose and method of use, the fees, and other matters about Facility Management (FM) in Turkey. In practice, the contractors regulate the management of residential buildings by submitting a printed text to the title deed, and it causes management problems in FM. Although it is possible to change the management plan later, providing this quorum in a collective structure consisting of thousands of independent sections is difficult since a 4/5 qualified majority is foreseen.

Methods / Methodology – This study examined different management plans used in residential buildings and determined the contract deficiencies. Qualitative data was obtained through the survey with 29 managers and 660 residents. In addition, judicial decisions were examined, and the effects of the regulations in the management plan on FM were discussed.

Results – In practice, it is observed that a uniform management plan is prepared for all residential buildings, regardless of their type and needs. It has been found that there are many disputes, especially on issues such as the management of common areas, renting, collection of dues and taking management decisions. These cases take a very long time and are very costly. Being meticulous during the preparation of the management plan solves the problems that may arise later to a great extent.

Originality – In addition to theoretical knowledge, the study differs from other studies in that it is supported by a survey and is an interdisciplinary study of law and FM.

Type of paper – Research Paper

KEYWORDS

Residential Buildings, Facility and Property Management, Management Plan and Management Cost.

INTRODUCTION

As a result of migration after the Industrial Revolution, the increasing population in cities has also increased the need for housing (Çeliker 2012). In line with this need, the Condominium Law was adopted in 1965. The granting of separate and independent property rights to independent sections resulted from these sociological and economic developments. The Condominium Law, which was prepared according to the social characteristics of 1965, has undergone some changes until today in the face of changing needs (Çeliker 2012). From the date of the law's adoption until this time, the perception of

[1] Professor, Department of Real Estate Development and Management, Faculty of Applied Sciences, Ankara University, Ankara, Turkey, tanrivermis@ankara.edu.tr, ORCID 0000-0002-0765-5347

[2] Corresponding Author, Dr. - Research and Teaching Assistant, Department of Real Estate Development and Management, Faculty of Applied Sciences, Ankara University, Ankara, Turkey, esrkeskin@ankara.edu.tr, ORCID 0000-0003-2778-9024

residence in society has changed, the cities have become more crowded and the need for housing has increased accordingly (Arcak and Erdoğan 1976). The provisions of the Condominium Law, which was prepared with the fiction of having a maximum of 10 independent sections in a single main structure, are far from meeting the needs of collective structures consisting of thousands of independent sections today. The increase in the number of independent sections and flat owners necessitates the preparation of a new Law. For this purpose, provisions on collective structures have been added to the Law in 2007, but it is still insufficient to solve the problems related to management.

The management plan is among the documents specified for the establishment of the condominium (Bozkurt 2010). The management plan is perhaps the most important document regarding the condominium, especially in the field of management. The condominium owners may determine the content of the management plan, which is in the nature of a contract, as they wish by the principle of freedom of contract (Kömürcü 2020). The existence of a well-made management plan is needed to solve many problems to be experienced in collective structures. Based on this assumption, the research questions are:

- Does the management plan affect the quality of management and residents' satisfaction?
- Who should be involved in the preparation of an effective management plan?

It is clearly stated in Article 28 of the Condominium Law that it is a contract that binds all flat owners. However, many problems are encountered in the preparation and implementation of the management plan. Management plans do not differ according to the facilities and all facilities are tried to be managed in the same way with standard texts. Especially in mixed-use buildings and multi-owner housing estates where there are many common areas, many disputes have to be resolved through litigation. Two large-scale urban transformation project areas in Ankara Province were selected to evaluate the role of management plan in collective structures.

LITERATURE REVIEW

When the studies in the literature are examined, it is seen that mostly the legal dimension of the management plan is discussed. Öktem Cevik (2010); emphasizes that the management in collective structures consists of more than one sub-unit and is organized as administrative management, it states that which flat owners' board will be authorized on overlapping issues should be regulated in the management plans. Bozkurt (2010) considers specifying the fixed rate based on square meters and the common expense and advance shares in the management plan to prevent existing problems. Another suggestion is that the authorities regarding the flat owners' boards should be clearly stated in the management plan. Çeliker (2012), on the other hand, underlines that the land registry directorates should not interfere with the management plan, and states that printed forms should be avoided during the preparation phase. Arpacı (1984) and Tekinay (1991) make a discussion about the bindingness of the management plan to the flat owners.

In the studies of Kaşıkçı (2014), Antalya (1996), Aksan Nar (2013) and Üner Er (2018); it is seen that the management plan is generally included within the framework of the Condominium Ownership Law, and there is not much study, especially on the management plan. The most important discussion about the management plan in these studies is related to the common areas. Şengül (2013) states that the common areas specified in the Law cannot be converted into independent sections even unanimously, and there is a gap as to whether the places such as the doorman's office and the shelter can be evaluated within this scope due to their usage characteristics. There is a difference of opinion in the literature on this issue. According to Göknar (1996), Germeç (2008), and Arpacı (1984), since these places are listed in the Law, they cannot be converted into independent sections in any way. Oguzman *et al*. (2022) and Şengül (2013) offer the opinion that the expression "probably considered a common area" is not valid for areas suitable for use on its own and can be converted into an independent section by contract. When the literature is examined, it is seen that there is no survey study on the management plan and its relationship with the management.

EVALUATION OF THE MANAGEMENT PLAN IN TERMS OF CONTENT

The building management plan regulates the management style, the purpose and form of use, the remuneration to be received by the managers and auditors, and other matters about the management (Öztrak 1967). Within the scope of management style in the management plan; the formation of the boards such as block condominium owners' board, island condominium owners' board, collective structure condominium owners' board, which are the management bodies of the collective structure, the meeting time of these boards, the method of calling for the meeting, the management of the meeting, the quorum, the nature and implementation method of the decisions to be taken, whether the management authority of the island condominium owners' board (if any) and the collective structure condominium owners' board will be given to the island representatives board and the collective structure representatives board, the number of members of the board of representatives and how they will be elected, whether a manager or a board of directors and an auditor or an audit committee will be appointed for the management and audit works, and if so, among whom and how they will be elected, the powers and responsibilities of the manager and the auditor, the accountability of the manager and the time of accountability, the audit time of the auditor, whether a temporary management will be established, and if so, how the temporary management will be formed and how long it will continue (Kömürcü 2020). Meeting times of the flat owners' boards, meeting, and decision quorum, type of call, selection of the manager/board of directors and auditor/supervisory board, authorities and responsibilities of the manager and auditor, the method and time of the payment to be made to persons such as cleaners, gardeners, security guards to be employed in the collective structures and other similar issues are referred to as management jobs (Condominium Law). Flat owners can determine other issues related to management in line with their own will. Provided that they are related to the management, other subjects desired by the flat owners can also be included in the management plan (Oğuzman *et al.* 2022).

The management plan can be evaluated in 4 basic categories in terms of legal, technical, administrative, and financial aspects. In legal terms, other legal regulations, especially the Condominium Law, must be appropriate (Esener and Güven 2010). Areas that are technically compatible with the project and allocated must be specified. From an administrative point of view, it means the establishment of management and inspection bodies. In financial terms, the operating budget should be established and the dues determined.

There is no form requirement regarding the management plan in the Condominium Law. It is sufficient to have it in plain written form, but it has to be signed by all floor owners (Öktem Çevik 2010, Belen 2000, Esener and Güven 2019). The issues to be regulated in the management plans can be freely determined by the flat owners, but of course, it is not possible to arrange them contrary to the mandatory provisions of the Law (Sirmen 2022). However, in this case, it would be more appropriate to consider only the inconsistent matters null and void (Arpacı 1984). The binding effect of the management plan is also a controversial issue. Some authors argue that it is a contract that binds all flat owners (Tekinay 1991).

The management plan given to the land registry directorate during the establishment of the condominium may become unable to respond to the new needs over time. For example, new facilities can be built in common areas and it may be necessary to regulate according to which criteria the costs of these facilities will be shared. In another example, the management plan submitted when establishing the condominium may not have been prepared by the nature of the collective structure or may have been acquired later. In such cases, it is possible to change the management plan. For this, the decision quorum must be reached. Otherwise, changes can be made through the intervention of the judge (Condominium Law). On the other hand, those who oppose the change can apply to the court for annulment. In classical condominiums, the management plan can be changed with the votes of four-fifths of the condominium owners (İpek 2022).

The expenses of the porter, heater, gardener and watchman should be paid equally (Condominium Law). The law has adopted the equal participation rate in this regard and has specified one by one, which subjects will be equally responsible. It has brought a broader interpretation of the expenses to be shared in proportion to the land share. It has been regulated that there should be participation in expenses such as insurance premiums, maintenance, protection, reinforcement and repair expenses and manager's pension at the rate of the land share (Condominium Law). When examined in terms of classical condominiums, this arrangement, which seems to be sufficient, is insufficient in some cases in terms of collective structures. There is uncertainty, especially in cases where some parts of the building are used physically and partial ownership of the condominium is established. If these expenses arise from the construction, maintenance or protection of common areas and facilities, then all property rights holders will be obliged to participate in these expenses.

The most common problems arising from the management plan in practice are as follows;

• The situation where the use of common areas is allocated to some flat owners as if they have been used as if the right of ownership has been established, or the case where an independent section is allocated to the owner with the management plan, although it is mentioned as a common area in the architectural project, (roof, garage, garden, parking lot, etc.)

• The presence of provisions contrary to the property rights of the independent sections of the flat owners,
• There are regulations contrary to the rules such as neighborhood and good faith rules.

RESEARCH METHODOLOGY AND/OR METHODS

Large-scale urban transformation projects in Ankara Province were examined and fieldwork was aimed to be conducted in two different project areas that are high in terms of three criteria such as the area of the project area, the number of people affected by the project and the number of independent units built after the transformation. For this purpose, the Dikmen Valley Urban Transformation Project, which is the first slum transformation project, and the North Ankara Entrance Urban Transformation Project, which is one of the largest urban transformation projects in Turkey and transformed by a special law, were determined as the research areas.

In surveys, face-to-face interviews and mail surveys were conducted with both residents and managers. In the survey, residents were visited and standardized questionnaires were used to administer the questionnaire to the adult member of the family in households and to the managers. The data collected through the surveys was analyzed and focused on identifying problems related to the management plan. In the analysis of all data collected through the survey, summary charts were created using the SPSS package program, statistical validity test and significance of the results were also evaluated. The selection of residents to be surveyed in the research area was carried out systematically with the help of address lists. Surveys were conducted voluntarily, and it was aimed to continue the fieldwork until the minimum survey sample was completed by selecting a substitute household instead of the household that refused to be surveyed.

In addition to the survey, face-to-face interviews conducted in the research areas were used as descriptive information where needed during the interpretation of the survey results. In addition to this, interviews were held with existing blocks and site managers in both project areas, as well as individuals and institutions providing professional management services. In this way, it has been made possible to identify the main problems arising from the management plan in the post-transformation areas and to present the solution proposals with a participatory approach.

The target audience of the study was determined as the residents, block and site managers residing in the North Ankara Urban Transformation Project and Dikmen Valley Transformation Project areas. There are 8,152 residences in 182 blocks in the North Ankara Urban Transformation Project area and 2,520 residences in the Karacaören region. In the Dikmen Urban Transformation Project area, there are 4,590 residences in 54 blocks. A total of 15,262 households were defined as the target group for the household surveys in the two project areas. With the classical sampling method, the sample was determined as 632, but a total of 660 owners and tenants were surveyed (Keskin 2023).

It is aimed to apply a survey to the block managers (182 blocks in the North Ankara Urban Transformation Project area and 54 in the Dikmen Valley Urban Transformation Project area, a total of

236 blocks) and the site managers and, if any, outsourced managers. Since some sites are managed by professional companies and temporary construction management is ongoing, a total of 29 management companies and managers from both project areas were surveyed and the management structure was assessed based on the results.

Prior to the survey, a pilot study covering 20 residents and 2 managers was conducted in both study regions and the comprehensibility of the survey was tested. After the pilot application, the field application was started with the approval of the project team after the necessary arrangements and corrections were made.

During the fieldwork phase, it was planned that the researcher would conduct surveys with 8-12 owners or tenants per day. Since the professional service was procured during the field implementation phase, the data were reviewed by the researcher in the field, and after the adequacy of the surveys applied every day was checked for the purpose, telephone checks were also made to ensure healthy data collection. In addition to the controls made during the survey, telephone checks were applied to 10% of the number of surveys conducted by each interviewer. Surveys with inconsistent answers were cancelled and if it was determined that this was not a conscious practice, the interviewer was changed. The surveys approved as a result of the controls were entered into the data after the final controls were made.

RESULTS

It is expected that the demographic characteristics of the residents of the selected North Ankara Entrance Urban Transformation Project and Dikmen Valley Urban Transformation Project areas will differ from each other. Because housing prices, education levels and income levels in the two areas differ from each other (Keskin *et al.* 2023). The rate of ownership is 74.8% in North Ankara and 53.2% in Dikmen (Table 1). It was found that the rate of home ownership was higher in North Ankara and the rate of ownership in Dikmen was below the provincial and national average due to the fact that housing was given to those who were reconciled from the households affected by urban transformation projects and housing prices were relatively lower. While the rate of post-transformation building management by a professional management company was 43.8% in North Ankara, this rate was found to be as low as 28.6% in Dikmen (Table 1).

Table 1 Characteristics of the residents surveyed and the management model of the structures (Keskin 2023).

Selected Variables and Their Descriptions		Urban Transformation Projects					
		North Ankara		Dikmen		Total	
		Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Management type	Professional management	200	43,8	58	28,6	258	39,1
	Management by residents	257	56,2	145	71,4	402	60,9
	Total	457	100,0	203	100,0	660	100,0
Ownership status	Owner	342	74,8	108	53,2	450	68,2

	Tenant	115	25,2	95	46,8	210	31,8
	Total	457	100,0	203	100,0	660	100,0
Gender	Women	243	53,2	104	51,2	347	52,6
	Men	214	46,8	99	48,8	313	47,4
	Total	457	100,0	203	100,0	660	100,0
Age	18-26	70	15,3	19	9,4	89	13,5
	27-37	180	39,4	45	22,2	225	34,1
	38-48	101	22,1	51	25,1	152	23,0
	49-59	77	16,8	61	30,0	138	20,9
	Over 60	29	6,3	27	13,3	56	8,5
	Total	457	100,0	203	100,0	660	100,0

The tendencies and opinions of those living in urban transformation areas on problem identification and solution development were evaluated. It is clear that 59.1% of the residents in North Ankara and 97.0% in Dikmen identified problems in building/site management, and the tendency to identify problems in North Ankara is lower and weaker than in Dikmen. In North Ankara, the main problems identified by residents in the transformation areas were reported to be lack of maintenance and orderliness (24.1%), noise (12.22%), disputes or problems between neighbours (12.22%), and problems in building quality and lack of insulation (12.22%). In Dikmen, according to the owners, the main problems are insufficient parking (19.80%), lack of maintenance and disorder (12.69%), lack of solutions to existing problems (11.68%), and lack of cleaning and disinfection (11.17%), and it is noteworthy that there are differences in the problem determinations between the two regions (Table 2).

Table 2 Basic management problems and solutions of housing estates/buildings according to owners and tenants (Keskin 2023).

Selected Variables and Their Descriptions	Urban Transformation Projects					
	North Ankara		Dikmen		Total	
	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Security issues	27	10,00	14	7,11	41	8,78
Lack of maintenance and repair	65	24,07	25	12,69	90	19,27
Lack of cleanliness	19	7,04	22	11,17	41	8,78
Management plan participation	7	2,59	23	11,68	30	6,42
Insufficient parking lot	13	4,81	39	19,80	52	11,13
Inadequate heating	18	6,67	13	6,60	31	6,64
Noise problem	33	12,22	11	5,58	44	9,42
Condominium meetings	6	2,22	7	3,55	13	2,78
Conflict / problems in neighborhood relations	33	12,22	14	7,11	47	10,06
Failure of the manager to fulfill his/her duties	33	5,93	8	10,66	41	7,92
Others (such as poor construction quality, insufficient insulation)	16	12,22	21	4,06	37	8,78
Total	270	100,00	197	100,00	467	100,00

In North Ankara, there are many problems arising from the management plans made during the project development and title deed registration phase. This is because the management plans were made by the TOBAŞ General Directorate, while the right holders and those who later acquired the residences had no idea about the management plan before the settlement in the new residences (Table 3). Although the management plan must be signed by all condominium owners, it was found that the condominium owners did not read the management plan because they did not have any information about important information such as land share. Another practice is that the owners give power of attorney to construction company officials or other person. This has been giving rise to whether the management plan should be changed.

In North Ankara, 16.7% and 30.3% of the respondents in North Ankara and Dikmen, respectively, answered “1 year” to the question “If the building/site management is carried out by persons elected by the owners, do you know how long the management bodies serve?”. It is observed that 79.4% of the residents in North Ankara and 66.9% in Dikmen do not have information about the term of office of the people elected to the building/site management and in general, the level of interest of the owners and tenants in the building/site management is very weak (Table 3).

Table 3 Knowledge about the content of the management plan (Keskin 2023).

Selected Variables and Their Descriptions		Urban Transformation Projects					
		North Ankara		Dikmen		Total	
		Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Do you know how many square meters the land share of your house is?	Yes	28	6,1	15	7,4	43	6,5
	No	429	93,9	188	92,6	617	93,5
	Total	457	100,0	203	100,0	660	100,0
If the building/site management is carried out by persons elected by the owners, do you know how long the management bodies serve?	For 1 year	43	16,7	44	30,3	87	21,6
	For 2 years	7	2,7	4	2,8	11	2,7
	For 3 years	3	1,2	0	0,0	3	0,7
	No idea	204	79,4	97	66,9	301	74,9
	Total	257	100,0	145	100,0	402	100,0
Do you have any information about the extraordinary general assembly of the building/site management?	Yes	6	2,3	8	5,5	14	3,5
	No	59	23,0	35	24,1	94	23,4
	No idea	192	74,7	102	70,3	294	73,1
	Total	257	100,0	145	100,0	402	100,0

However, it has been very difficult to meet the conditions for making changes in the management plan. Similarly, it is often not possible to convince the owners of the change and to obtain a majority (4/5) or unanimous vote on the desired changes. In this respect, it is remarkable that valuation, distribution of the land share and preparation of the management plan must be handled with a professional approach. This needs to occur during the project development process and these works must be carried out under the responsibility of real estate development and management professionals. It was determined that similar problems were encountered in Dikmen Valley.

Descriptive Summary of the Managers Who Participated in the Survey

In the North Ankara Urban Transformation Project area, which is one of the largest urban transformation projects in Turkey, 15 management companies and site managers were surveyed, and the results were summarized. Among the managers surveyed, 10 are male and 5 are female, 10 are university graduates and 5 are high school graduates. 7 of the managers have 5 years or more of experience in the field of building and site management, and 8 of them have less than 5 years of management experience. It could be induced that diversity is blended among the experts who participated in the survey.

To start with, a total of 14 managers were surveyed in the Dikmen Valley Project Area, and all of them provided management services created by the owners' board. 4 of the managers are women and the others are men. Of these, 5 managers have more than 10 years of experience in the field of building/site management, and the experience period of the rest varies between 1-9 years. There are generally no major problems between the block manager and the site management board. In addition, there are no major problems arising from the building and site management plan. Therefore, there was no need to amend the management plan. It has been stated that a lawsuit was filed by the building and site management against the flat owners and tenants because only 3 tenants did not pay their dues, and the lawsuits are still ongoing. Among the problems arising from the legislation and management plan; The framework of the duties and authorities of the managers is not clearly defined in Condominium Law No. 634, and the sanctions regarding noise, odor and other pollutants in the legislation regarding the use of common areas according to the provisions of the Turkish Civil Code No. 4721 and the Turkish Code of Obligations No. 634 are not known clearly. However, the debatable expression of no need to amend the management plan leads to examining the view of the resident on the management plan and the result is presented as follows.

Perception of residents in North Ankara and Dikmen on Management plans

It was observed that those who bought residences in both areas did not have enough information about the management plan (Table 4). They also do not have enough information about the Condominium Law. It is seen that the biggest problem in the areas is usually related to the common areas. Especially in projects where social adaptation is important, such as urban transformation areas, there are many conflicts due to the use of common areas (Table 4). This has generated contradiction from the earlier argument on the management plan. The fact that the use of common areas such as car parks, elevators, and sports halls and participation in the common expenses of these areas are not regulated in detail in the management plan causes different problems. Since it is not regulated in detail in the management plan, there is no alternative but to resort to litigation to resolve the dispute. This way is both costly and harms the social relations of people who have to live together.

Table 4 presents information on survey participants of 660 residents from North Ankara and Dikmen. The types of residence surveyed are 2+1, 3+1 and 4+1 flats. Induction could be made that there is a connection between the number of family members and the type of residence they are living in. Besides that, the pattern of residence occupancy in North Ankara is different from those in Dikmen. The number of residents staying in 4+1 flats is more than those who occupy 2+1 flats in North Ankara. However, the residents in 2+1 flats are more than those staying in 4+1 flats in Dikmen. Still, there is a similarity which is the majority of residents are staying in 3+1 flats in both locations. This implies that the demographic population in both locations differs slightly and could have a different effect on their view on the issues relating to management plans and facility management.

Furthermore, the finding revealed that the majority of the residents do not have management plans before they purchased their flats. In North Ankara, 6.1% received a management plan before they purchased their house while 93.9% did not receive a management plan before they purchased their residence. In Dikmen, 7.4% of the residents received a management plan while 92.6% of the residents did not receive a management plan. Through findings, it was discovered that the management plan is very essential and effective in solving several problems that arise. Based on the survey report, 89% of the residents from North Ankara and 92% of the residents from Dikmen agreed that the management plan needs to be available before the purchase of the residence because it could have solved some litigation issues. Consequently, it would have reduced the cost of litigations.

The use of common areas has been ranked as the highest among the main problems in management plans, followed by the collection of dues and expenses in common areas. In both North Ankara and Dikmen nearly 44% and 42% respectively of the residents agreed that using common areas has been the main problem with a management plan. Similarly, the residents from North Ankara and Dikmen, rated dues and expenses collection as 39% and 36% respectively as the second highest main problem with management plans.

In summary, information in Table 4 has made it clear that management plans are essential to be made available before residential purchases take place and the facility management should have an attractive approach to address the issues relating to using common areas and collection of dues and expenses.

Table 4 Results of the survey study.

Selected Variables and Their Descriptions		Urban Transformation Projects					
		North Ankara		Dikmen		Total	
		Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Type of residence	2+1	36	7.9	61	30.1	97	14.7
	3+1	376	82.3	135	66.5	511	77.4
	4+1	45	9.8	7	3.4	52	7.9
	Total	457	100.0	203	100.0	660	100.0
Did you read the management plan before you purchased your residence?	Yes	28	6.1	15	7.4	43	6.5
	No	429	93.9	188	92.6	617	93.5
	Total	457	100.0	203	100.0	660	100.0
Will the detailed preparation of the	Yes	406	89	187	92	593	89
	No	51	11	6	8	57	11

management plan be effective in solving existing problems?	Total	457	100.0	203	100.0	660	100.0
What is the main problem with management plans?	Problems using common areas	203	44	86	42	289	44
	Problems in making decisions on boards	81	17	44	22	125	19
	Problems in collecting dues and common area expenses	173	39	73	36	246	37
	Total	457	100.0	203	100.0	660	100.0

It is thought that many of the problems can be solved with the detailed preparation of the management plan. Therefore, there is a positive relationship between the first research question "Does the management plan affect the quality of management and residents' satisfaction?" and the results. Residents in the research areas have high a rate of complaints about management services.
Based on the second research question; the preparation of management plans is recognized as a specialized task. Because it is related to real estate and asset management as well as legal knowledge. In this context, the management plan should be prepared by people with interdisciplinary knowledge and experience and should be shared with the residents in detail. In this context, determining a participatory approach will be effective both in evaluating different opinions and in reducing the problems that may arise in the future.

DISCUSSION AND/OR CONCLUSIONS

Although there are references to classical condominiums in the provisions of the management plan, the management plan is much more important in terms of collective structures. Because both parcel and flat owners are more quantitative. The abundance of common areas, the variety of services provided, and the number of personnel also support the need for a detailed arrangement of the management plan in terms of collective structures. While many problems encountered in the practice of collective structures can be solved with a detailed and well-prepared management plan, unfortunately, many problems are subject to judgment as a result of the acceptance of printed management plans.

There are problems in the collection of management expenses due to the limited powers of managers in the legislation and management plan or problems arising from restrictive articles in the management plan. There are also problems in benefiting from the common areas of blocks and collective structures (or housing estates) and participating in their expenses. When the disputes that are the subject of litigation are examined, it is seen that the problems arising from the management plan are on issues such as the use of common areas, how much the dues will be, who will pay how much dues, at what time intervals the meetings of the board of directors should be held, how the cleaning will be provided, parking lot sharing, how security will be provided, how the pool or garden works, if any, will be carried out, and whether the apartments can be used as workplaces.

Supreme Court of Appeals[1] all condominium owners responsible for the damages and repair costs arising from damages to the common areas, but emphasizes that the Condominium Law, management plans and approved architectural projects should be considered together and a rational evaluation should be made in terms of the determination and use of the common areas.

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A dear child has many names: understanding *hybrid* in higher education learning concepts and practices

Sandström, N.[1], Tuhkanen, T.[2], & Nenonen, S.[1]

ABSTRACT

Background and aim - University learning landscape is in digital transformation. The learning environments that support student-activating approaches and that make use of the possibilities of digitalization are more common, when developing the practices and directions based on the experiences from the pandemic era. There is not yet a shared understanding on how the digital and physical learning environments will be re-configured. The paper describes the iterative processes of redefinition and applies semiotic analysis to examine the function of language in learning environment conceptualisations and management.

Methods / Methodology - The data are based on a university case study from Finland. The iterative process is mapped using action research and semiotic analysis. The analysis of the processes is validated by peer reviews between researchers.

Results - The results indicate that as advanced digital technologies and practices evolve, the shared definitions and concepts and a common language are required throughout the strategy and functions as well as facilities management. Additionally, a network-cantered view is required to change shared practices and processes in both physical and digital learning environments. The change requires network learning and the respect of various stakeholders within an ecosystem.

Practical or social implications - The study contributes to multidisciplinary research on learning landscapes enriching the conceptual understanding of both the change and the pertinent elements that compose the landscape. This is a key factor in campus and facilities management. The practical contribution provides understanding of the networked structures and shared language needed to develop digitally and physically appropriate solutions.

Type of paper – Full research paper

KEYWORDS

Hybrid learning, learning environment, semiotics, facilities management, networks.

INTRODUCTION

The use of communal, public, and private space was dramatically altered in the spring of 2020 as institutions changed their modality of working and teaching. Schools and universities among many other institutions operated in a totally new manner compared with the time before. It was stated already

[1] University of Helsinki, Faculty of Educational Sciences & University Properties and Facilities, niclas.sandstrom@helsinki.fi, Siltavuorenpenger 5 A, FI-00014 University of Helsinki, Helsinki, Finland
[2] University of Turku, Educational Support Services, Turku, Finland

before campus lockdowns that hybrid environments will be a platform for learning and working in the future (Ninnemann et al., 2020; Triyason, Tassanaviboon & Kanthamanon, 2020; Lahti & Nenonen, 2021).

Universities had already earlier been using different technological affordances for teaching, as well, but the volume increased during the crisis (Zawacki-Richter 2021). The long-term effects of this disruption, however, are yet to be studied (García-Morales, Garrido-Moreno & Martín-Rojas 2021; Fűzi, Géring & Szendrei-Pál 2022). The capacities of individuals, as well as peer and community support enhanced the speed of digital transformation in the university learning landscape. The speculation of a "new normal" in terms of learning environments points to something different happening in approaches to teaching and in the learning environments and campus – one can even wonder if something 'old' will ever return. While some expect little more than a return to pre-pandemic life, with perhaps minor tweaks, others see a transformation, even unavoidable (Sardar, 2021).

Changing times will set changing norms. Incorporating technology into pedagogy is now the norm rather than the exception. These norms change the symbolic value and meaning of learning environments. The classroom or lecture theatre are configured to the norms of being present on the lessons. Such norms of presence are transforming and there are consequences also the learning landscape: physical and digital infrastructure which is supporting learning and teaching in universities.

The goal of this paper is to describe the iterative process of redefining learning environments in one university both linguistically and semiotically. There is not yet a shared understanding on how the digital and physical learning environments will be re-configured or how their self-assembly and intertwining will take place. More interpretation is needed to make sense of the hybrid learning and teaching practices and how the post-pandemic learning environment should look like. The research question guiding the work is *how to better understand and identify the function of language and the meaning-making processes in conceptualising and managing learning environments.* For this, a linguistic and semiotic analysis is applied, serving to clarify current and future developments in ever more hybrid and blended learning landscapes especially in higher education.

The paper is structured as follows: the terminological remarks are followed by laying out conceptual trajectories, then the method is presented, leading to results and semiotic analyses and conclusions with limitations and future remarks.

HYBRID LEARNING AND LEARNING ENVIRONMENTS

The university uses a set of technical terms to guide its curricular planning processes that have to do with teaching spaces, room reservation and management of space and facilities.

The challenge is that there are often myriads of connotations and scopes of reference, with implications to who, when and how the equipment and resources are maintained, the spaces are allocated, and pedagogies are applied through different platforms that may or may not interconnect. The same goes for the administrational or support service vocabularies that differ from terminologies used by researcher-teachers. This way, hybrid teaching or hybrid space, for instance, can evoke very different connotations in different stakeholders.

Having long discussed this challenge in the shared vocabulary and even semantics of the terminologies, we find that a way to bring a method to the madness is applying semiotics, i.e., the study of signs and signification to understand and clarify differences and relations between concepts, linguistic and visual signs, and signification more generally. A viable approach is the semiotic square, a structural way of mapping similarities and oppositions of terms and concepts (Greimas, 1966; Greimas & Frastier, 1968). The semiotic square is an analytical tool used to map contrary, contradictory, and implied terms. Basically, its structurally coherent apparatus can be used to study the interlinkages of any terms. It is used in structural analysis of the relationships between semiotic signs through the opposition of concepts. In our study, the key terms or concepts are spatial and digital, which in their opposing terms are at play with physical and hybrid (Figure 1).

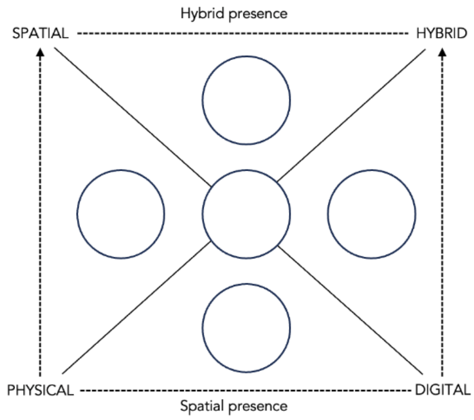


Figure 1 The semiotic square of presence in digital and physical realities.

Physical implies the spatial dimension of reality while digital refers to digital and physical existence. The spatial presence within physical learning environments have been guiding the educational vocabulary, practices, and meanings. The hybrid presence provides insights to realities, where the digital dimension enlarges the reality while the physical body is always located in physical reality. The semiotic square makes it visible that, while it might be typical to build on physical and spatial entities, it very well could be important to see them as equivalent entities and emphasise to balance between them instead of perceiving them as exclusive of each other.

Integration of digital and physical places

When investigating the word ‘hybrid’, one often refers to hybridisation. Hybridisation means combinations and fusion, and accordingly, growing ambiguity i.e., opaqueness and a plethora of interpretations. It dates back to Greek mythology, like ancient powerful beasts such as Hydra, and to biology, with "mixed creatures". For example, the Sphinx is a mythical creature with the head of a human and the body of a lion with the wings of a falcon, usually, guardians of temple entrances.

Hybrid is interpreted somewhat differently in different fields. 'Hybridity', 'hybridisation', 'hybridism' or 'hybrid' are terms used by scholars in the social sciences as well as literary and cultural studies. Colloquially, we have hybrid TVs (analogue + digital), hybrid cars (electronic + fuel), hybrid work (home + office), and hybrid conferences (face-to-face + online). A hybrid space can be based on many combinations, constituted by virtually anything and of elements of very different scales and nature. According to Mele et al. (2023), the development and use of physical and digital objects and applications (i.e., *phygital* resources) in a *phygital* context (i.e., spaces and places) affect the customer journey in a phygital manner to enable the development of new forms of phygital experience. They maintain that phygital is not simply the combination of physical and digital, but a nexus, assemblage, or hybrid. There are definitions that stress the role of phygital in terms of connectivity to the digital and virtual environments, or as a mix that is integral to create an ecosystem. In their literature review, Mele and colleagues (2023) identified that several scholars see that the amalgamation of physical and digital contexts and spaces shape a phygital space featured by the development of bonds, bridges, and webs that enable interaction and sharing between different human and non-human actors.

Hybrid learning and learning environments

As combinations of two or more things, hybrid spaces can tentatively be categorised according to the
1) characteristics, e.g., physical and virtual, public and private, natural and artificial
2) fields, e.g., technology and culture, science and religion, humans and machines
3) functions, e.g., learning and entertainment, work and housing,
4) roles e.g., student and teacher, consumer and producer, expert and layperson (Karjalainen, Heinonen and Taylor 2022)

These pairs or dichotomies could be expanded by for instance the ones laid out by Stommel (2018), examples of which include: analogous pedagogy / digital pedagogy; passive learning / experiential learning; use of tools /critical engagement with tools; machine and machine-like interaction / human interaction.

Eyal and Gil (2022) discuss a three-fold framework for hybrid learning spaces. In their approach, hybrid beyond blended is not so much a mixture as it is "more of a 'compound'" (p. 22). Due to the frequent movements of users that carry their "hybrid" devices connected to the mostly wireless networks (e.g., a smartphone is a phone and a camera but also a scanner and a measuring tape), hybrid learning spaces are dynamic environments enriched by digital worlds and social networks that come together. On more concrete levels, e.g., design patterns and various learning and teaching approaches might promote them.

Hybrid learning is an educational model that entails some students attending class in person while others join virtually – from home, from the library or from almost any location where they can be online

(Sonntag et al. 2019; Raes et al. 2020). Hybrid learning enables a more flexible and immersive learning environment than typical on-site learning or online learning. In relation to blended learning (online learning that complements in-person classes) and e-Learning or distant learning (educational courses that are solely delivered electronically), which have been widely put into practice by educators during the past decade, hybrid learning is an evolutionary teaching method (Kohls 2019; Saichaie 2020). It emphasizes applying digitalized teaching methods to class activities to deliver a digital, interactive, and engaging class atmosphere, while ensuring that the students attending remotely can enjoy the same learning experience (Lu & Zhang 2023; Pei et al. 2023).

Hybrid environments enable physical, digital and social learning to be merged in a new way. There are opportunities and threats to these kinds of environments, as well (Lu & Zhang 2023). Hybrid courses provide instructors more freedom in structuring them. In a hybrid learning environment, where activities can be authentic but at the same time perceived as ill-defined, leaving students more at ease or more anxious, such flexibility generates both opportunities and obstacles. As Cook et al. (2020) state, the establishment of hybrid learning cultures and practices that allow for involvement and engagement outside the conventional boundaries of the institution, course, or learner role, is what hybrid learning and hybrid learning environments often entail. In higher education, traditional dichotomies including online-onsite, digital-physical, formal-informal, university-society, disciplinarity-transdisciplinarity, learning-teaching, study-work, individual-collective, and student-citizen tend to be crossed, intertwined, or avoided. According to Robson et al. (2022), university lecturers in the UK recognised the value and importance of interactive teaching and indicated that the post-pandemic lecture would and should make greater use of this. The staff also recognised the value of asynchronous lecture videos within a blended or flipped approach. They state that the pandemic has engendered changes in attitudes and practices within UK higher education. This entanglement of ideas, formats, and domains that transforms into new, complicated combinations is how hybridity is centred (Stommel 2012).

METHODS

The data are based on a university case study from Finland. The goal of the case study is to define, together with different experts from research and various representatives from university services, what hybrid learning environments and their profiles post-2020 are. The purpose of this definition process was to create shared understanding for teachers using the learning environments and to stakeholders providing the learning environments. The stakeholders included participants from teaching and learning support services, general administration and library, ICT support, and facilities management and research.

The iterative process is mapped using action research approach. Action research combines theory and practice (and researchers and practitioners) through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework. Action research is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning (Avison et al. 1999). The analysis of the processes aimed to identify themes and patterns which were typical for forming a shared understanding within a group of experts from different disciplines. The data were collected from several sources including workshops, literature review, benchmarking, surveys, usability walkthroughs and meetings. The phases and data sources are presented in Table 1.

Table 1 Phases of action research process and methods for data gathering.

Phase	Literature review	Workshops	Meetings	Document analysis	Survey	Usability walkthroughs
1 Mapping the need for shared definitions	x	x	x	x		
2 Clarifying the need		x	x	x	x	x
3 Proposing the first set of definitions		x	x			
4 Validating the definitions		x	x			

The data were approached systematically: The first phase "Mapping the need for shared definitions" aimed to understand the past, present, and future of the learning environment definitions at the case university and in general from the literature e.g., definitions proposed by the national Ministry of Education and Culture (Anon., 2021). Methods and data gathering sources included document analysis e.g., from different internal instructions where learning environments were mentioned: instructions for teaching, instructions for audio-visual equipment in classrooms, instructions for classroom reservation systems to mention but a few. The different systems allowing access to the used definitions were listed too. Additionally, the national definitions in Vocabulary of Education by Ministry of Education and Culture were reviewed. Finally, a review of pertinent literature on pedagogy and learning environments was performed, producing the following three steps:

1. learning environment definitions used at the case university
2. following the existing literature connected to academic learning environment e.g.
3. mapping and defining the need for the shared definitions in the meetings

The results were discussed and co-developed in the meetings and workshops among participants from different support functions for teaching in the university including experts from information technology, audio-visual technology, learning technology, library, time schedule organizers, space reservation system developers, learning space architect and pedagogical experts.

The second phase "Clarifying the need" aimed to approach the need for shared definitions by testing the usability of the latest learning environments designed to the hybrid learning. The methods were usability walkthroughs, workshops for the classroom testing and feedback surveys. Additionally, we gathered practices from other universities and discussed the results in meetings and workshops. The participants were the same people than in the first phase, but we had also visitors from other universities as well as teachers joining the usability walkthroughs and feedback surveys of the classrooms.

The third phase, "Proposing the first set of definitions" aimed to present the first draft of the shared definitions. With a similar group of participants, we developed the classification of learning environments including the variety from the basic level to advanced environments for hybrid teaching. The workshops and meetings were the gatherings where the co-written document was elaborated systematically.

The fourth phase, "Validating the definitions" aimed to test the classification of learning environments. The constant set of workshops has been organised for the management of learning services, teachers and education designers.

The semiotic square served as a frame to analyse the results of the different phases to the holistic picture for the researchers. The elements of physical and spatial as well as digital and hybrid formed an archetype for the learning environments semiotically representing spatial or hybrid presence. Figure 2 summarises how the findings were positioned in the semiotic framework.

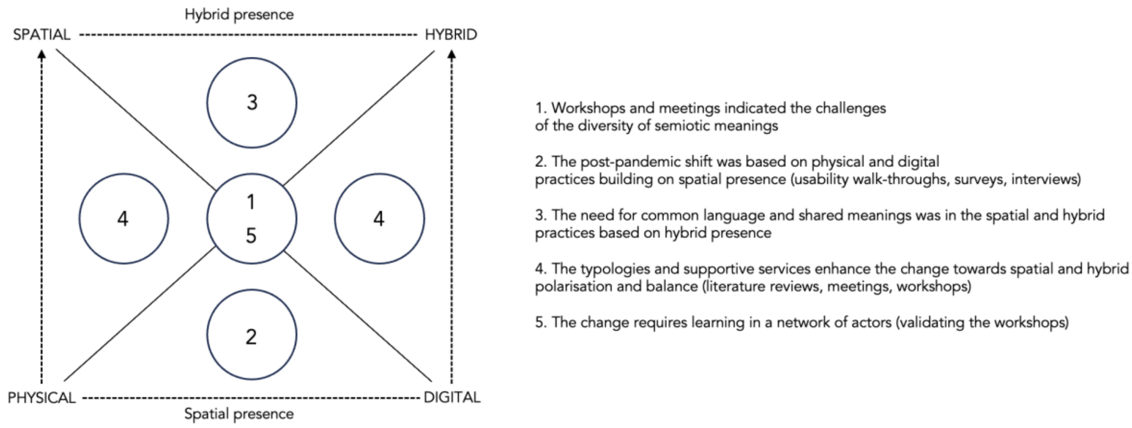


Figure 2 The findings positioned in the semiotic square of presence in digital and physical realities.

RESULTS

The iterative process of action research as well as the semiotic square made it possible to form a framework for network learning in changing learning environments. First, we found out that the definitions and concepts for hybrid learning were presented internally in 21 systems and in 20 instruction and guidance documents of the case university. The instructions had nearly similar definitions, albeit not equal. They were developed in evolving layers including also traditional expressions and more modern wordings. The ways to describe classrooms with hybrid teaching features were either very technical or did not provide enough information about the potential for different uses. It was evident that there is a need for shared definitions and concepts and a common language as advanced digital technologies and practices evolve. Such concepts are required throughout the strategic, tactical, and operational instructions and functions for hybrid learning environments.

However, the change is not only rational reduction of instructions and integration of systems – it is a cultural act, and three semiotic results will enlighten the transformation process needed.

Semiotic perspective 1 Digital and spatial awareness

The normative definitions for hybrid learning are embedded in multimodal learning. Hybrid can be a wider concept as just integration of physical and digital elements (see e.g. Mele et al. 2023). Based on the literature review, the understanding of these elements requires awareness (Sandström and Nevgi 2022) and competence (Lejon et al. 2021). Awareness of learning environment and didactic implications of the space to learning and teaching activities is accurate, be the learning environment physical, digital or both. Having physical or hybrid presence is the fundamental change to apply pedagogical scripts. *Didactic spatial competence* (DiSCo) by Leijon et al. (2021) highlights how a teacher must make didactic choices based on proven experience and science when it comes to designing learning activities in a specific learning space. DiSCo includes planning for teaching and learning in a variety of learning spaces that support the pedagogical ideas; it also entails implementing, that is to critically reflect on and use affordances and meaning potential in various learning spaces, to have agency and competence to act and re-act during teaching and learning in various learning spaces and perhaps first and foremost, to use the space in a meaning-making process together with the students – that is to create a place for learning. Related to this is *semiotic space awareness* (Sandström & Nevgi 2022). According to them, the value acts that work as signs of moral character (i.e., how people position themselves in relation to others, respecting or defying their socio-material space) are important in structuring space use. Semiotic space awareness is the spatial-moral positioning of a subject in the socio-material and semiotic space. People's positionalities primarily take place in the socio-material space, and the dimensions we discuss focus on how value acts – the signifying moments that affect users of a shared space – are produced and interpreted in space and place.

Integrating these two theoretical concepts, we propose *the didactic spatial and digital awareness* as a central node in the actor and network learning in changing learning environments. This means that the learning environments should be defined in a way that teachers can use them for increasing awareness of the potential of them.

Semiotic perspective 2 Support and services

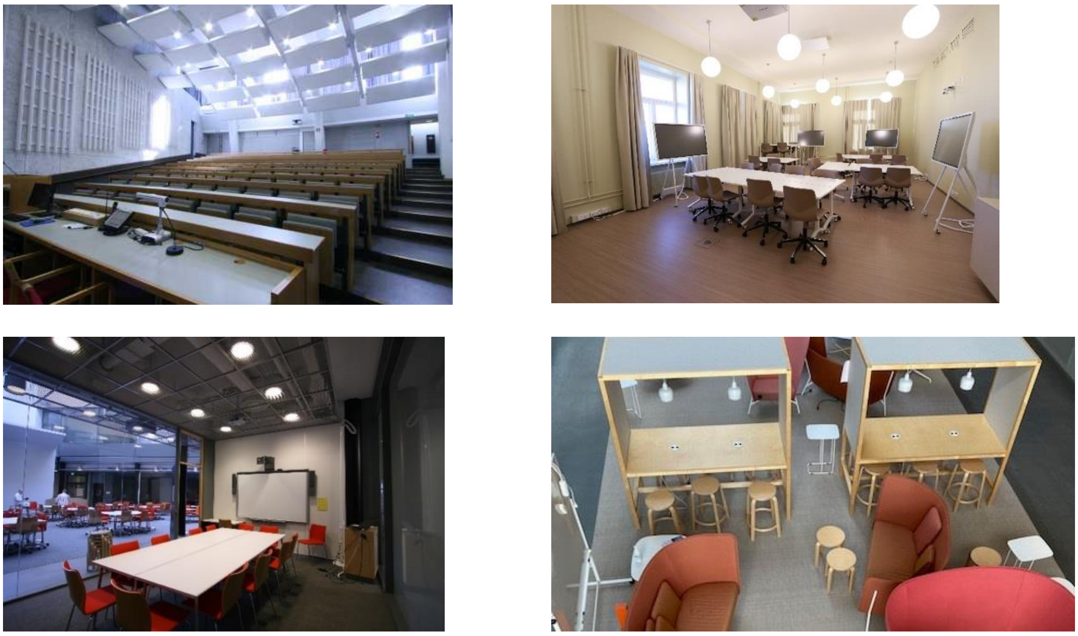
While the traditionally more common physical presence is changing towards hybrid presence, it means that both physical and digital entrance allow participants to join the teaching and learning situation. To open this affordance for actors, there is a group of experts on the backstage organising the functional elements for successful learning and teaching experiences.

The action research iterations indicated that instead of scripting the instructions about the separate functions of elements of hybrid learning environment, one need to integrate the information in a comprehensive way. Teachers and students using the hybrid learning environments are not interested in functions of part of the entity but from the potential and fit factor of the solution. Pedagogical scripts should help teachers to choose the suitable options. The options should be easy to recognize, use and operate.

To balance the existing variety in instructions the typology of learning environments for teacher-led studying and independent studying was co-created in three iterations. At first the learning environments were described by classifying one star, two star, and three-star learning environments. The solution included a purposeful value statement. The second iteration included a small – medium – large classification, but it was understood as a concrete form and size of the physical space. The third iteration was concluded by using colour codes:

The blue learning environments are rooms equipped with basic audio-visual features. Such places are mostly usable for the traditional ways of teaching or studying individually. The environments can be enriched by bringing own device. The yellow learning environments are likewise room-based, but they are designed to flexible use of the physical and digital features. The green learning environments are rooms, areas, or group of rooms, which can be used for different purposes like to traditional presentation, group work setting, hybrid event or even for the art performance. The orange learning environments are in shared used, and they are designed to public areas like lobbies, cafeterias, and other social facilities. In individual studying the yellow facilities are for group working while the green facilities serve studying alone together e.g., in working lounge and orange facilities will serve as meeting zones for maybe shorter timeslots.

These for typologies shed the light also to the requirement of support and services to use the space in the way it is supporting different pedagogical choices. The multi professional team providing the affordances for the diverse learning experiences has also different challenges when the issues deal with conventional meaning of using spatial solution for learning and enrich it with technology- blue and yellow typology is based on this assumption. Green and orange facilities are designed to the assumption that the space is for diverse purposes and the user groups vary based on the functions they choose to use. They are spaces that are not dedicated to one audience like students, faculty, or staff but rather can serve all three in the same place to enable interactions while saving space and money alike. The awareness of the use of all four types of learning environments requires not only classroom awareness but more, the understanding the use of digital and spatial instrument as a learning landscape.



Picture 1 Basic equipped, flexible, multi-used and community shared learning environments with spatial and digital features (source https://tilavaraus.helsinki.fi/fi/).

Semiotic perspective 3 Learning among actors in the network environments

The new meanings and their affordances require actor learning, not only in the teaching situation but in the full chain of actors providing the support and physical and digital infrastructure for learning. A network-centred view makes the ecosystem visible. This is a way to reduce the number of instructions and systems, while the base line for them is not in the organisational structure but in the ecosystem structure. The change to network structures requires network learning, whose foundations are on actor learning. This framework provides a venue for conventional and unconventional learning practices in a way that the learning environments and pedagogic scripts are in harmony (see Figure 3).

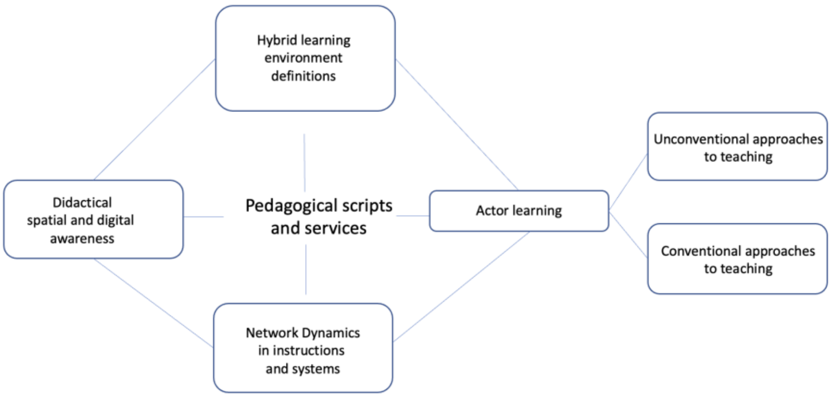


Figure 3 Dynamics and nodes for actor and network learning in changing learning environments.

Facilities management has the essential role to join in actor learning and support it with the co-produced services. The network dynamics, thus, seem to form the new management discipline to be realised in campus and facilities management.

CONCLUSIONS

This paper intended to describe the iterative processes of redefining learning environments in universities both linguistically and semiotically. Such interpretation is needed to make sense of the hybrid learning and teaching practices and how the post-2020 learning environment should look like. The three semiotic findings guide universities to see spatial and hybrid presence as the determinants of hybrid learning environment as spatial and digital entities (Raes, 2022). The classification of room-based and area-based learning environments provide typologies which include the different historical and pedagogical layers of learning environments without value statements. The results point out also the process of change and process of learning – not only individually but in a network and ecosystem. The learning environment is not provided or supported by a group of actors but by a network of actors.

The results contribute to multidisciplinary research on learning landscapes enriching the conceptual understanding of the change. This is a key element in campus and facilities management. The practical contribution provides understanding of the networked structures needed to develop digitally and physically appropriate solutions. Incorporating technology into pedagogy is now the norm rather than the exception. These norms change the symbolic value and meaning of learning environments. The classroom or lecture theatre are configured to the norms of being present on the lessons. Such norms of presence are transforming and there are consequences also for the learning landscape. Common definitions will shape the norms and practices within higher education and follow the development of digital society and work life, i.e. where to guide and how to prepare the learners. We believe that hybrid learning is the way forward, but it can be difficult to establish a common foundation between the physical and the digital entities without diving into the semiotic meanings of the concepts.

An identified potential weakness of the study is using semiotic components translated into English when the materials were collected and the action research conducted in Finnish. This might cause some semiotic discontinuities. However, the concepts like hybrid and digital bear similar connotations and semantics over language boarders. The objective approach of the action research is captured by using two researchers individually organising findings according to the data gathering protocol. The process could be figured out in another university to increase both validity and dependability or trustworthiness (Seale 1999).

The practical contribution provides understanding of the network structures needed to develop digitally and physically appropriate solutions. The hybrid learning environment has several potential benefits for facilities management. One is that it changes the value proposition for facilities managers from just maintaining a building to delivering quality learning experiences through efficient use of facilities and resources (Haddadi & Johansen 2019). This implies that they should have a deep understanding of how each type of facility resource contributes to student - and teacher - success, which will help them determine where to invest the resources.

Another benefit is the ability to provide customized environments suited to different types of learner needs. Hybrid learning environments can be difficult to manage because of the diverse needs of their users. Facilities management staff should focus on creating clear conceptual clarity for hybrid learning environments. This means that all stakeholder groups should understand how the spaces work, including how students are expected to use them, and what kinds of activities will take place in the premises. Facilities managers can also help support services such as IT or maintenance understand how they should contribute to hybrid learning environments in order not to confuse their roles (see e.g. Nenonen et al. 2023).

An item for future research would be to focus on the post-occupancy evaluation of hybrid learning environments when the norms of hybrid learning have been configured and laid out. The role of room-based solutions will be decreasing and multiuse and sharing of facilities will increase. Follow-up studies from the point of view of functionality and economics should be a much-awaited source of information for future campus management.

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Extending informal/private networks: Exploring the influence of communication technologies on student social connectedness (SSC) in the context of a hybrid university learning environment (HULE)

Wheele, T.[1,2,*], Lindkvist, C.[2], Haugen, T.[2], Weber, C.[1,3], Windlinger, L.[1]

ABSTRACT

Background – This research aims to explore the influence of communication technologies on student social connectedness (SSC) in the hybrid university learning environment (HULE). This is important since SSC is indicated as negatively impacted in digitally orientated learning environments, yet limited research explores the influence of communication technologies (e.g., 'Teams', 'Moodle', or 'WhatsApp') on SSC for in-person communication.

Methods – This qualitative study uses observational data from 19 master level students at a Swiss university over 5 months, beginning September 2022, and 5 group interviews conducted at the end of the semester with 10 of the students. Socio-materiality is applied to understand how self-reported and observed perceptions of SSC are influenced by communication technologies in the HULE.

Results – Categorised by 3 indicators of SSC, the findings reveal 3 themes: socialising outside the main view, social support in close connections, and spending time to shape a sense of belonging. Students built or maintained SSC in informal/private spaces on-campus and online. Whilst being in-person was favoured, communication technology (mainly 'WhatsApp') helped extend informal/private interactions.

Originality – This innovative study impacts existing pedagogic approaches to the university by using socio-materiality to explore how communication technologies influence SSC in the HULE.

Practical implications – The study offers in-depth analysis, which is difficult to generalise across students within different disciplines, universities, or countries. With greater empirical research, facility management disciplines could bridge the gap in translating these findings into a clear framework for universities to adopt in-practice and facilitate SSC across student populations.

Type of paper – Full research paper

KEYWORDS

Hybrid learning, university environment, education, digitalisation, student social connectedness.

INTRODUCTION

[1] Workplace Management, Institute of Life Sciences and Facility Management, ZHAW (Zürich University of Applied Sciences, 8820, Zürich, Switzerland
[2] Institute of Architecture and Planning, NTNU (Norwegian University of Science and Technology), 7491 Trondheim, Norway
[3] School of Psychology, Faculty of Health and Medical Sciences, University of Surrey, Guildford GU3 7XH, UK
[*] Correspondance: theresa.wheele@zhaw.ch (T.W.)

Background

The hybrid university learning environment (HULE) is a growing black box for student social connectedness (SSC). SSC is recognised by architectural industry experts as one of the biggest challenges of new digitally orientated learning environments, particularly in the HULE (Nobre et al., 2021). Yet despite the apparent losses to SSC, students generally favour a hybrid style of learning (Allen and McLaren, 2021; Eyal and Gil, 2022; Wheele et al., 2023). The HULE offers a modern and less rigid approach to learning where students have greater flexibility and constant access to knowledge and communication streams (Van der Meer et al., 2021). However, it is not fully understood what sacrifices are made for this. Communication technologies are being rapidly adopted without significant knowledge of their influence on SSC, which is particularly concerning since the learning process is innately social (Thacker et al., 2022). This article addresses key aspects of facility management (FM) responsibility for people, place, and technology in the HULE. Identifying where improvements can be made to support SSC both on and off campus helps support FM in facilitating these adjustments.

This study emerged to address these issues. It explores SSC in a master level hybrid style university course in Switzerland. The cohort includes 19 students who were all working alongside their studies. Qualitative data was collected using participant observation and interviews. Findings are analysed using socio-materiality theory. Socio-materiality examines links between people, place, and technology when building or maintaining SSC. It emerged in the early 2000's as a reaction to the social embeddedness of material aspects in society and organisations (Orlikowski, 2007). Two key findings emerge from the study. Firstly, students sought interactions in informal/private spaces, both online and on-site for building or maintaining SSC. This included students turning cameras off during online Teams video calls yet turning cameras on during small group break-out sessions. Secondly, although communication technologies helped build or maintain SSC, particularly in informal/private spaces, students favoured being in-person for building or maintaining SSC. This in-depth study provides key insights that have not been considered previously considered in the HULE. It hopes to inspire further research to enhance validity and robustness across different student populations and position the overall student experience as a crucial aspect to address when managing learning environments of the future.

Disciplinary challenges in the HULE

Numerous challenges surround the study of SSC in the HULE. Such challenges are significant to FM in managing new demands from the HULE which are both tangible and intangible. University campuses are knowledge-based creative environments that rely on being both cognitive and social spaces (Huhtelin and Nenonen, 2021). Buildings have been known to afford diverse relations of users in a campus as a physical place (Kärnä et al., 2013). The HULE brings new unknowns to the management of campuses that are less tangible and are currently not measured in terms of quality. The meanings of socialization in the HULE are obscure when it comes to managing this phase from an FM perspective (Huhtelin and Nenonen, 2021). There are several reasons for this obscurity.

Firstly, hybrid learning is not widely defined. Different disciplines have varying terms to describe similar situations, which makes developing research challenging. The HULE is a digitally enabled learning environment that provides both physical and digital learning synchronously and asynchronously (Bülow, 2022; Goodyear, 2020; Wheele et al., 2023). Whilst it is commonly associated with other terms like blended, hybrid is used since it is more widely understood outside pedagogy, encouraging interdisciplinarity (Eyal and Gil, 2022; Siemens, 2005). Interdisciplinarity is necessary as hybrid embeds physical and digital space (architecture); social meaning of place (sociology); teaching/learning (pedagogy), and supportive processes for the interaction of people, place, and technology (FM).

Secondly, expectations of the HULE are still in a state of flux as universities transition from the HULE as a necessity (during the later stages of the COVID-19 pandemic) to a legacy. During the pandemic, the university learning environment was constantly evolving in an era of uncertainty, making it difficult to gauge the long-term consequences of research (Biwer et al., 2021). Although a hybrid style of learning emerged prior to the pandemic on a smaller scale, it was propelled into widespread use during the pandemic by different courses, disciplines, and universities to varying extents (Skulmowski and Rey, 2020). In this way, COVID-19 encouraged rapid mass adoption of hybrid learning with little time to fully comprehend its impact (Biwer et al., 2021; Raes et al., 2020; Thacker et al., 2022). Many changes were deemed temporary, but whilst many drastic changes are diminishing as the pandemic passes, there is a general understanding that a hybrid style of learning is set to stay (Allen and McLaren, 2021; Bülow, 2022; Eyal and Gil, 2022; Sandström et al., 2022). As communication technologies are being continually developed, such as the Meeting Owl, there is little knowledge about how students engage with these technologies or how they aid SSC compared to being in-person (Allen and McLaren, 2021; Raes et al., 2020; Skulmowski and Rey, 2020). SSC is indicated by architectural industry experts as one of the biggest challenges of the HULE, yet the uncertainties brought by the pandemic have made addressing the influence of the HULE on SSC challenging and unpredictable.

Theoretical underpinnings: Socio-materiality and social connectedness

In this article, a socio-material perspective offers a holistic understanding of the influence of communication technology on SSC in the HULE by exploring the disciplines of sociology, architecture, pedagogy, and FM. Since pedagogic research traditionally focused on the theory and practice of teaching/learning, this helps recognise the value of more intangible or subjective concerns that contribute to the overall student experience (Siemens, 2005). Socio-materiality emerges from a field of organisation studies to acknowledge multiple, emergent, and shifting assemblages that are innate to contemporary organising (Orlikowski, 2007). It is a way of thinking that addresses social aspects as embedded in material objects (Jarrahi and Nelson, 2018). In this way, socio-materiality brings material and institutional orders to technology as it transcends the context in which it applies. This recognises that digital and physical space interact differently across place and time, which is useful when considering the HULE (Acton, 2017; Leonardi, 2013). Since socio-materiality also accounts for the social aspects of learning, it helps the research account for networks tying people to virtual and physical space as interconnected and continually emerging (Acton, 2017; Macleod et al., 2019). This could help understand how some communication technologies in the HULE (e.g., 'Teams') might influence SSC differently from others (e.g., 'WhatsApp') or in-person communication. Recognising place as both a physical space and a highly complex social function brings attention to the more intangible qualities of SSC, which are currently lacking in FM strategies for managing the HULE. In recognising the value of these more intangible social aspects, the findings aim to support the development of a framework of SSC in the HULE and help FM guide university professionals in managing these changes post-COVID.

RESEARCH PROBLEM

Social connectedness is challenging to research since it is subjective, hard to measure, and constantly changing. However, addressing social connectedness is important since it can significantly impact academic performance, student retention, health and wellbeing, identity development, or long-term career success (Tran and Gomes, 2017). Various context specific means of measuring social connectedness have emerged. For instance, the social connectedness scale by Lee and Robbins (2000) measures school student connectedness by eight statements based on connectedness, affiliation, and companionship. Similarly, Hare-Duke et al. (2019) explore "thwarted belongingness of interpersonal needs" in mental health contexts, and Bailey et al. (2017) measure social connectedness by Facebook friendships. This spread across different contexts and disciplines makes it hard to find a suitable measure. Frieling et al. (2018) introduce 3 indicators of social connectedness: socialising, social support, and a sense of belonging, which offer categorisation of SSC in the HULE. These indicators centre on urban design and planning theories that explore social structures through social network analysis (Frieling et al., 2018). Although developed in the context of urban places, such indicators have potential contributions for the intangible socio-material environment of the HULE, which this study examines. However, socio-materiality can build on the work by Frieling et al. (2018) by examining intangible aspects of the socially embedded environment that makes up the HULE. Categorising the research into the 3 indicators of SSC brings greater clarity and organisation to the complex and intangible aspects of people-place interactions within SSC, which is necessary for FM to know for managing the HULE as a facility. These 3 indicators are subsequently explored by the authors in their literature review for SSC in the HULE (Authors, 2023) and applied to this research. The 3 indicators are defined as follows:

1) Socialising is considered the type or frequency of interaction between people. For example, the language students use, or the frequency that they chat together in class.
2) Social support is the provision or receipt of guidance or help. For example, how openly a student asks a question in class, or receives emotional support when struggling.
3) Sense of belonging is the feeling of being part of a group and relates to identity. For example, connecting with the landscape around the university or purchasing university memorabilia.

It is important to note that qualities in the categories can be intangible and interconnected, highlighting the role of socio-materiality in helping clarify this (Frieling et al., 2018; Wheele et al., 2023). Whilst it is challenging to provide fully robust and inclusive measures of SSC, these indicators provide a practical means of developing a more rigorous and structured understanding of SSC in the HULE, which is important for the future management of the university. In highlighting these challenges, we reveal the importance of developing research through the key research problem and question as follows:

• *Research problem: Communication technologies in the hybrid university learning environment (HULE) are not well-understood for their influence on student social connectedness (SSC).*

• *Main research question: How are communication technologies influencing student social connectedness (SSC) in the hybrid university learning environment (HULE)?*

RESEARCH METHODOLOGY

Research design

This qualitative study explores a master's level cohort of 19 students on a hybrid style learning course based in Switzerland. All students completed their studies whilst working (with varying percentages of part-time employment). Students were approximately 20-30 years old with a mix of genders, although the majority were male. Students were from several countries, but most understood the colloquial dialect of Swiss German. The teaching language was English and conducted by various lecturers. The university is spread across various campuses, but on-campus lectures were conducted in the same classroom on a small campus outside the city. The classroom layout changed between classes with high tables and chairs in some classes, and more traditional tables in rows in other classes (see figure 1). On the course, students were told when to be on-campus and when to be online, which was mostly followed with occasional exceptions when some students joined online instead of on-campus. Data collection and analysis were conducted within the guidelines of the Norwegian Centre for Research Data (NSD) ethics agreement granted by the NSD because the research is conducted for the Norwegian University of Science and Technology (NTNU) in Norway. The agreement ensures participants remain anonymous by anonymising students, the course, and the university. The observational study of all 19 students was conducted in-person and online, including observation of visual and vocal interaction. 10 out of 19 students responded to the interview request and were divided into groups based on availability. Interviews were conducted in-person with 3 sessions of 2 participants, 1 session of 3 participants, and 1 session of 1 participant. Interviews lasted approximately 60 minutes. The sample offers in-depth analysis of individual experiences over 5 months with over 5 hours of transcript data.

Figure 1 The on-campus lecture room.

Data collection

Data was collected by the leading author using field notes, audio, and video recordings. Observational data began at the start of the course and was collected over 5 months, which included weekly classes that lasted 3 hours (excluding holiday or exam periods) both online and on-campus. Interview data was collected at the end of the course when participants met the leading author on-campus. The interview included 10 semi-structured questions that explored student experiences with social connectedness on the course based on the 3 indicators of SSC. As part of the questions, participants were asked to organise 15 images of learning environments (based on the multiple sorting procedure) based on learning preferences and SSC. Participants were also asked to respond to observations of class observations. Data was recorded and stored on servers of the leading author's two affiliated universities in Norway and Switzerland, which only the leading author can access. Steps were taken to ensure reflexivity and consistency by maintaining regular meetings with the other authors.

Data analysis

The data was analysed thematically under 3 key themes based on the 3 indicators of SSC: socialising, social support, and sense of belonging. Further, interview data was analysed by coding questions thematically based on informal and formal spaces within the 3 indicators of SSC. These themes were then considered in relation to the influence of communication technologies, underpinned by socio-materiality and the understanding of technology as integrated within the network. Socio-materiality is used to understand human and technology relations and the role of individual experiences in relation to place. In focusing on the influence of communication technologies on SSC in the HULE, these values are outlined in the results and discussion. As there were 10 participants in the interviews, the purpose was to get in-depth insights into individual experiences with SSC. The data gathered was extensive and only key quotes or observations are presented.

FINDINGS

In the findings, we identify 3 key themes: socialising outside the main view, social support in close connections, and spending time to shape a sense of belonging. This recognises the importance of more private/informal spaces (e.g., WhatsApp) for building or maintaining SSC in the HULE compared to more overlooked/formal spaces (e.g., a class lecture). Addressing these places is challenging and we recognise that categories are not definitive because places might be momentary, in transition, or mixed between online and on-campus. For example, two students interacting could be overheard in an on-campus lecture, and students speaking online might feel concealed without using the video camera. Therefore, terms like informal and private help acknowledge the momentary emergence of certain places from within the entanglements of society in space (Kohls et al., 2022; Weber et al., 2021).

Socialising outside the main view

Through the observational study, students did not interact as frequently online as on-campus. In the interviews, participants suggested that the camera influenced interactions online.

"yeah some are not putting the cameras on not even in the small groups [teams breakout rooms]"

"if the cameras off and you're sitting there it's like I'm not a part not really a part of this you just observe"

However, communication through 'formal' technology platforms 'Teams' or 'Moodle' was often not as desirable for socialising. This also depended on the lectures' knowledge or ability to use the platforms. Expectations of technology as a tool for learning did not always match between students and the lecturer, highlighting the innate discrepancies between students and lecturers in the learning process.

"when you're watching live it sometimes feels like you're watching like bad YouTube videos"
"one lecture used a funny tool where you have a virtual classroom to bring people to put the camera on"
"to tell people to turn on the camera like this way it was really unpolite somehow"

Finding a balance for these discrepancies is challenging to ensure that the ways students depend on technology positively impact their learning experience. For instance, students sought interaction through 'informal' platforms (chiefly 'WhatsApp') to engage in private interactions. Whilst the lecturer might decipher this as a distraction, students valued these informal interactions for socialising and finding support. Further, WhatsApp groups had various levels of 'formality', with the WhatsApp group created for the entire class (but excluding the lecturer) feeling more formal than other groups.

"if I don't understand or something is funny then sometimes we text behind the camera like private chats"
"we would have WhatsApp calls on and we're watching the things but don't interact with the lecturers"
"its very official but a lot of subgroups or other groups where I share everything and I don't care"

Socialising on-campus was important to participants, with socialising during the breaks or outside the main lecture being most enjoyable when in-person. However, socialising beyond the lecture was more likely to occur following prior organisation that had occurred through WhatsApp.

"I really like the breaks onsite, at home you're just online or you sit there on your phone"
"we had this pre-meeting day and the chance to eat together, it was really good to make connections"
"actually we met like in Starbucks this was like uhh I have problems studying at home"
"we try for everybody who has the time to take time out but it's mostly after the onsite lectures"
"we organise to meet via WhatsApp, it's like informal kind of formal but yeah"

Social support in close connections

Developing connections between students and the lecturer was important for building networks of support, with participants valuing being on-campus when seeking guidance or clarity on a topic.

"I'm really connected to the teachers' and I've not had this before, I've never really eaten lunch with my teachers before, maybe it helps to pass the exams"
"after like two or three days of studying at home you're just in your bubble of knowledge"
"when you see the gestures... it's easier for you to join the conversation and follow the conversation"

Being on-campus was especially important during the breaks or between the main lecture sessions.

"its easier in the break to ask a question in the group as well as the professor"
"you have to kind of explain OK this was going on and maybe in the classroom [onsite] the teacher would overhear they're talking about this"

Participants recognised the additional value of more private interactions that helped them feel more supported. Connecting beyond the classroom was important to help relate with others on the course.

"we had introduction days it was kind of a playful get together and I think it was really important for me"
"we are really 100% all of us are working so 100% of the people understand what you're going through so this also helps me to feel connected"
"it was always guidance with professors or drinking a beer then going home not in this free environment"

Encouraging connections to develop or remain strong was helped through communication technologies. However, this was challenging in more open or 'formal' online learning spaces.

"it was so unpersonal when I was on the online lecture always I thought I am alone there nobody sees me and nobody hears me I can do my thing"
"at home you're very isolated and so its hard to see, do my colleagues struggle with the same things?"
"It feels different to hit that unmute button and say ehh I would say it's this answer, it doesn't work"

Spending time to shape a sense of belonging

When questioned about feelings of belonging and identity to other students and the university, participants often gave incredibly in-depth, personal or minute details both on-campus and off-campus.

"the library reminds me of the classical university, but I feel you're doing this if you're a med student which I did not so I'm happy to not be sitting there"
"maybe it's a childhood memory, nowadays we have screens and the university logo, a teacher in front"
"I have a neck pillow and some like therapy lamp next to me for when I get tired"
"the teams interface or seeing the participants names really means online meeting or university for me"

Communication technology was an important link for participants to feel connected when online, but it was not always positive in the formal space and could create a distraction from learning.

"when your cameras off you're just like a ghost"
"I'm the whole time looking at whose doing what, I don't know it's like a vicious scrolling down the faces"
"I don't know I always have one eye thinking, oh do I have a double chin or what's going on"

Being in lectures on-campus helped enforce an image of the group as united. Further, spaces around campus helped shape this image and build connections, with requests for more informal social spaces.

"I just missed the first day yeah there is like the group picture of everyone and I'm not there"
"there's not even a bar related to the university, oh one you always get this email, but nobody goes"
"there's no cafeteria around this campus, which is very necessary"

However, whilst spending time connecting with others or the university in-person was important, spending time alone or online was also valuable to reconnect with the self.

"commuting and traveling takes time, takes nerves, they go through your body and when you stay at home it's kind of peace you know it's like this makes you feel more free and more energy yeah like this"
"I'd say in terms of participating I see myself a little bit introverted so online I don't have to interact"

Table 1 Categorising the findings across formal and informal spaces.

Theme	Formal space	Informal space
Socialising	*- Cameras assist socialising* *- Being in-person is favourable* *- Lecturers must know how to use technologies effectively*	*- Informal technologies enable socialising outside the view of the main lecture* *- Socialising favoured in breaks*
Social support	*- Being in-person is valuable for further guidance and clarity*	*- More guidance/clarity sought in breaks and between lectures* *- Informal interactions in-person helped students feel more connected and supported*
Sense of belonging	*- Identities engrained in traditional images of the university*	*- Identities are highly personal* *- Time to connect with the self is important to shape identities*

DISCUSSION

Communication technology for SSC: An extension of informal/private networks

Students favoured interacting in more private/informal spaces when seeking to build or maintain SSC with the university, their colleagues, academic staff, or even themselves. For instance, students frequently avoided talking in online Teams lectures but voluntarily communicated through WhatsApp (often during the lecture) outside the guidance or tools provided by lecturers. This gave students agency to their learning, excluding the lecturer or other students from more personal interactions. Jarrahi and Nelson (2018) also found that the materiality of technologies afforded workers agency to configure technologies. Private WhatsApp chats helped conceal interactions that might otherwise happen in on-campus classes. Thacker et al. (2022) also recognise the importance of privacy for students to critically reflect and develop interests. Being in-person was described by some as draining, taking 'nerves' and 'energy' to travel through the body, implying that privacy was easier to control online. Online, students simply switched their cameras off or messaged via WhatsApp. The resulting interactions were often mundane, personal, or unrelated to the course, but impactful on building or maintaining SSC. Through

WhatsApp, students had the agency to hide, creating an invisible divide that distinguished them from each other and the lecturer. Further, WhatsApp afforded students agency to self-regulate, enabling them to create a privacy barrier and enforce a position of togetherness, similarly recognised by the agency of technology in other studies (Jarrahi and Nelson, 2018; Macleod et al., 2019). Whilst buildings afford diverse relations for users (Kärnä et al. 2013), technologies do the same in terms of flexibility of choice of technologies and their use for relations. FM cannot control this flexibility of choice over technologies among students, nor should they. To continue supporting diverse user relations, FM should be aware of personal technology use and its integration with formal academic platforms.

Building or maintaining SSC was found in formal spaces by students developing belonging to the self or the university, such as through the Teams interface, or the university logo. These spaces were less social online, where students had the agency to build their own networks and often configured places to avoid being seen. For instance, students would turn cameras off and not speak during online Teams lectures but turn the camera on and speak during small break-out sessions. This supports studies by Bülow (2022) and Goodyear (2020) who recognise the potential of online space to increase the agency afforded to students. In our study, the camera had power and agency by manifesting feelings of vulnerability in students, which they managed by turning it off and avoiding concerns like being 'observed', having a 'double chin', or undertaking a 'vicious scrolling of faces'. The experience of being 'a ghost' with the camera switched off anonymised and de-personalised students in a privacy shield. Despite students recognising the camera as a useful connection tool, it was disliked and described as 'impolite' or 'rude' when lecturers asked students to use it. Further, not all students used the camera in breakout sessions when it was expected by other students to see their colleagues and thus, they were afforded a 'right to disconnect', as Hesselberth (2018) explores in the paradigms of connectivity. Similarly, Tran and Gomes (2017) explore how identities are made by experiencing both connectedness and disconnectedness. Therefore, although technologies existed to help build or maintain SSC, students often opposed formal networks and needed clear guidance to accept it for building or maintaining SSC. Thus, online spaces existed as a shield or 'bubble of knowledge' for students, whereas being in-person was favoured to build or maintain SSC. This illustrates an intangible negotiation of space which differs in the physical and digital knowledge place. FM needs to consider how to balance hardware and software technology choices for the formal HULE to ensure knowledge places are both cognitive and social (Huhtelin and Nenonen, 2021) and not just a place of information exchange.

Lectures on-campus were important to formally bring students together and aid informal/private interactions, such as 'gestures' between students or the lecturer. These interactions often occurred outside the view of the whole class or during breaks, with on-campus lectures bringing a 'chance to eat together'. Extending interaction beyond formal lectures was important for building or maintaining SSC, with requests for more informal on-campus spaces, such as a 'cafeteria' or 'bar'. These interactions were difficult to achieve online and unfavourable, which Acton (2017) also recognises in places that enable student-led or informal interactions to emerge. Students often felt 'isolated' and 'alone' in online lectures, potentially reducing SSC despite the opportunities to connect through formal networks (like using the camera). Instead, students used informal networks online (mainly WhatsApp) to often help instigate or organise socialising in-person based around on-campus lectures. In this way, communication technologies extended opportunities to build or maintain SSC in private or informal spaces of the HULE beyond the space or time of formal lectures. Preference was made to building or maintaining SSC in-person, and the campus offered a place to reaffirm identity and reconstruct relations with the world. This was also found by Kohls et al. (2022) who recognised the importance of informal spaces on-campus, and Acton (2017) who recognise that the availability of coffee, food, or simply comfy furniture encouraged students to linger for longer and thus encouraged SSC to emerge. Further, this entangling of social and material elements is recognised by MacLeod et al. (2019) to help shape identity. This was found in our study not necessarily in formal lectures but in informal/private space and time. Through these findings, communication technologies were found to help students extend informal networks for building and maintaining SSC, which often occurred in the more informal/private spaces of the HULE.

Although limits exist to the generalisation of the study, the richness of data is informative and could be useful in helping develop a framework for university managers to apply when tackling the problems faced with SSC in the HULE. By following 19 students over 5 months, the findings are data rich and bring insightful contributions. Whilst 10 out of 19 students were involved in interviews based on participant availability, data robustness and richness would be improved if all students participated and if interview group sizes were equal. Bias is managed as effectively as possible by conducting interviews in the same location with the same furniture layout and question structure. Researcher bias is managed by discussing the research among the authors. Further research could be developed by gaining data from 1) a larger cohort of students with different backgrounds, and 2) perspectives from academic staff. This is important since SSC is subjective and varies across universities, course levels, and disciplines (Biwer et al., 2021; Hesselberth, 2018). Further, academic staff could highlight aspects overlooked by students (e.g., conducting group work tasks in rooms designed to inspire interaction) but are instrumental for building or maintaining SSC. This study brings insight into the current trends of SSC as experienced by students in a HULE. It has scope to expand into future research to encourage framework development for SSC in the HULE, which university management professionals can apply.

CONCLUSION

This article explores the influence of communication technologies on SSC in the HULE through the research question: *"How are communication technologies influencing student social connectedness (SSC) in the hybrid university learning environment (HULE)?"*. It focuses on the HULE since this style of learning is being widely adopted and seems set to stay (Bülow, 2022). Through qualitative data collection, we found that students socialised outside the main view, sought social support in close connections, and spent time shaping a sense of belonging. We found that students controlled their privacy in online lectures, creating a less personal space that is harder to build or maintain SSC. Instead, they built or maintained SSC in more informal/private spaces. Students independently used WhatsApp to help extend these networks. However, students favoured being in-person when trying to build or maintain SSC. By using a socio-material way of thinking, this article highlights how SSC is linked between people, place, and technology. This recognises the role of informal networks for building or maintaining SSC, with communication technologies helping extend these networks. Alike Acton (2017), Bülow (2022), Goodyear (2020), and Kohls et al. (2022), this aims to develop innovative approaches to unravel student experiences in the HULE, with an in-depth focus on SSC. This hopes to expand traditional pedagogic approaches, raise awareness of the topic, and guide future FM decisions of the HULE post-COVID to better account for SSC in informal/private spaces.

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Assessing Classroom Indoor Environment from a User-Centric Perspective: A Preliminary Study

Huiying (Cynthia) Hou[1]

ABSTRACT

Background and aim - This paper emphasises the significance of evaluating classroom indoor environment performance from the perspective of students. Recognising this need, this study adopted a user-centric approach to evaluate students' perception of classroom environment based on a university in Hong Kong. The aim was to gain insights into the significance that students attribute to various parameters of the indoor classroom environment.

Methods / Methodology - This study devised and implemented a user-centric performance assessment framework based on the Analytic Hierarchy Process (AHP), as well as a survey based on the framework. 288 students from various types of classrooms participated in the survey, in which they ranked the perceived relevance of multiple classroom environment performance parameters according to their perceived significance. Analysed were the weightings and rankings of the performance parameters.

Results - The ranking results derived from the AHP analysis shed light on the students' perceptions of the relative significance of various environmental parameters. The fact that "facilities and services" received the highest weighting for importance demonstrates the significance of post-occupancy operation management. Male students place more importance on "indoor air quality" than female students do on "thermal comfort" Students in lecture halls prioritise "seating plans" and "temperature" whereas students in general classrooms prioritise "seating layout" and "fire safety".

Practical or social implication - The findings of this study have practical implications for higher education institutions in designing and managing classroom environments. They recommend considering factors such as classroom layout, illumination, temperature control, and acoustics to create optimal learning spaces. By adopting a user-centric approach and actively seeking student feedback, educational institutions can continually improve indoor classroom environments, ultimately contributing to enhanced learning outcomes. Prioritizing comfort, engagement, and adaptability in classroom design can play a pivotal role in promoting academic success in higher education settings.

Type of paper - Full research paper

KEYWORDS

University classroom, classroom environment, student perception, AHP.

INTRODUCTION

The nexus relationships between learning environment, students' psychological/physical condition, and learning outcome have been thoroughly examined in the education literature (Barksdale et al., 2021;

[1] Department of Building Environment and Energy Engineering, The Hong Kong Polytechnic University, cynthia.hou@polyu.edu.hk

Lan et al., 2023). Yet, the learning environment is vaguely defined in these studies, alluding to a hybrid location where learning activities occur. Architectural and engineering literature rarely discusses how students perceive the classroom's internal environment. Yang and Mak (2020) attempted to comprehensively evaluate the building service design aspects of university classrooms and investigated students' perceptions of university classroom engineering design elements. This study analysed the relationship between environmental data (such as thermal environment, acoustic environment, illumination, and indoor air quality) and human perception data (such as satisfaction) for the first time. However, the evaluation of architectural elements in classrooms, which research has shown to have a significant impact on student learning outcomes, was absent from their study. In order to advance Yang and Mak's (2020) research, it is necessary to combine architectural and building services elements into a comprehensive evaluation framework. This study employs a user-centered methodology to evaluate the classroom environment from the students' perspective in order to enhance future classroom management and design. The AHP method was then used to structure and validate the focus group discussion.

LITERATURE REVIEW

Adopting a user-centric approach towards resilient classroom

A user-centric approach shall be adopted in understanding the importance of and satisfaction with the built environment, as highlighted by previous studies examining occupant comfort (Puteh et al., 2015; Mihai and Iordache, 2016; Andargie et al., 2019; Day et al., 2020; Hou et al., 2023a; Hou et al., 2023b). This approach recognizes that the perceived quality of indoor environments, encompassing parameters like thermal comfort, visual comfort, acoustic comfort, and indoor air quality (IAQ), significantly influences occupants' overall comfort and satisfaction. Particularly in classroom settings, where students' well-being is a primary concern, prior research has predominantly focused on the relationships between IAQ and thermal conditions and students' welfare (Mishra et al., 2017; Jiang et al., 2018; Abdel-Salam, 2019; Wang et al., 2021; Rodríguez et al., 2021). While some efforts have been made to integrate holistic indoor environmental quality (IEQ) parameters, such as IAQ, acoustics, noise levels, lighting, and thermal aspects, into these investigations (Bluyssen et al., 2018; Korsavi et al., 2019; Korsavi et al., 2020), these approaches remain less prevalent. Moreover, from a system control perspective, it is essential to consider how IEQ parameters affect system performance in classroom indoor environments. Among building service systems, ventilation systems are frequently scrutinized, given their profound relevance to IAQ and thermal comfort (Gao et al., 2014; Petersen et al., 2016; Dorizas et al., 2018; Liu et al., 2018; Haddad et al., 2021; Choe et al., 2022; Cheng et al., 2022). In essence, adopting a user-centric approach not only improves the understanding of how indoor environmental factors affect occupants but also helps in crafting environments that genuinely enhance well-being and satisfaction, particularly in educational settings like classrooms.

Classroom environment performance parameters

The development of an evaluation framework for university classroom environments hinges on the careful selection of critical parameters. Extensive research in this domain has identified key factors that warrant attention. These encompass indoor air quality, thermal comfort, lighting conditions, and acoustics, as well as considerations related to furniture design, ergonomics, and post-occupancy assessment (Choi et al., 2014; Brink et al., 2021). These studies underscore the significance of parameters such as ventilation, temperature control, lighting quality, acoustic optimization, ergonomic furniture, and the collection of user feedback to inform classroom design and management practices. Of these parameters, thermal comfort emerges as the most commonly studied aspect in university classrooms. Notably, some studies exclusively rely on subjective data to gauge indoor environmental quality (IEQ) performance (Ramprasad and Subbaiyan, 2017), while others adopt an integrative approach by combining both subjective and objective data for a comprehensive analysis (Ricciardi and Buratti, 2018; Zuhaib et al., 2018; Yang and Mak, 2020). This body of research predominantly utilizes subjective data to capture occupants' perceptions of the classroom environment, forming a critical foundation for the development of evaluation frameworks.

In the evaluation of indoor environment quality (IEQ), particularly in university classrooms and higher education institutions, four key performance aspects are commonly assessed:

- Thermal Condition: Among these aspects, thermal comfort stands out as the most frequently examined factor in the context of university classrooms.
- Lighting Condition: Lighting quality, encompassing factors such as illuminance levels, color temperature, and glare reduction, plays a pivotal role in IEQ assessment.
- Acoustic Condition: Effective communication and learning are influenced by acoustic conditions, including ambient noise levels, reverberation time, and speech intelligibility.
- Indoor Air Condition: Indoor air quality (IAQ), which relates to factors like ventilation rates, pollutant control, and their impact on cognitive performance, is another crucial dimension of IEQ assessment.

In the reviewed literature, two distinct approaches to assessing indoor environmental quality (IEQ) in classroom settings were identified. Some studies rely exclusively on subjective data, focusing on occupants' perceptions of the classroom environment, as exemplified by research conducted by Ramprasad and Subbaiyan (2017). In contrast, others take a more comprehensive approach, gathering both subjective and objective data to conduct integrative analyses of IEQ. Notable examples of this approach can be found in the studies conducted by Ricciardi and Buratti (2018), Zuhaib et al. (2018), and Yang and Mak (2020). This multifaceted method combines perceptual insights with quantifiable metrics, offering a well-rounded understanding of IEQ dynamics within classroom environments.

METHODOLOGY

AHP method and its application in the study

The aim of this study is to evaluate the indoor environment from the perspective of students. Analytic hierarchy process (AHP) is considered to be suitable for this user-centric approach because it allows students to provide input and weight the importance of different parameters according to their own perceptions and priorities. AHP is a well-established method for decision-making and problem-solving that allows for a structured and comprehensive evaluation of multiple criteria. In the context of assessing classroom indoor environment performance, it provides a systematic way to consider various factors simultaneously, reflecting the complex nature of indoor environments. AHP is adept at combining quantitative data (e.g., rankings of parameters) with qualitative data (e.g., students' perceptions), providing a balanced view of the indoor environment's significance based on both objective and subjective measures (Hou et al., 2020).

Regarding the selection of pairs of environmental parameters, the process likely involved careful consideration and students' judgment. The application of AHP usually begins with a comprehensive list of potential criteria and then narrow them down through a series of steps:

- Initially, all relevant parameters are identified based on existing literature, expert opinions, and the study's objectives. This step aims to encompass as many relevant aspects as possible.
- The AHP process involves comparing each parameter with every other parameter to establish their relative importance. These pairwise comparisons are usually conducted through surveys or expert consultations.
- The collected data from pairwise comparisons are often normalized to ensure consistency and meaningful comparisons. This step helps create a consistent scale for assessing importance.
- With the normalized data, the AHP algorithm is applied to calculate the final weights and rankings of the parameters.

Development of performance assessment framework (AHP hierarchy)

The process of developing and selecting the evaluation framework involved a series of five Focus Group Discussions (FGDs). In each FGD, students were encouraged to freely discuss their perceptions of classroom environments based on their personal experiences at the university. The participants were guided to collaboratively construct a hierarchical framework for assessing classroom performance, drawing from their own interactions with various classrooms. The researcher played the role of a moderator, maintaining objectivity and ensuring that the participants' opinions were the focal point. The initial objective of the first four FGDs was to co-create a framework for evaluating classroom performance, with the participants actively contributing their insights. At the conclusion of each FGD, the facilitator presented the evolving framework to the participants for confirmation and feedback. In the fifth FGD, participants were presented with four different evaluation frameworks developed in previous sessions. They were invited to provide comments on the suitability of these frameworks. Subsequently, participants engaged in a voting process to determine the most appropriate evaluation framework among the options. A three-level classroom environment performance assessment framework was then developed based on the results of the FGD (Figure 1).

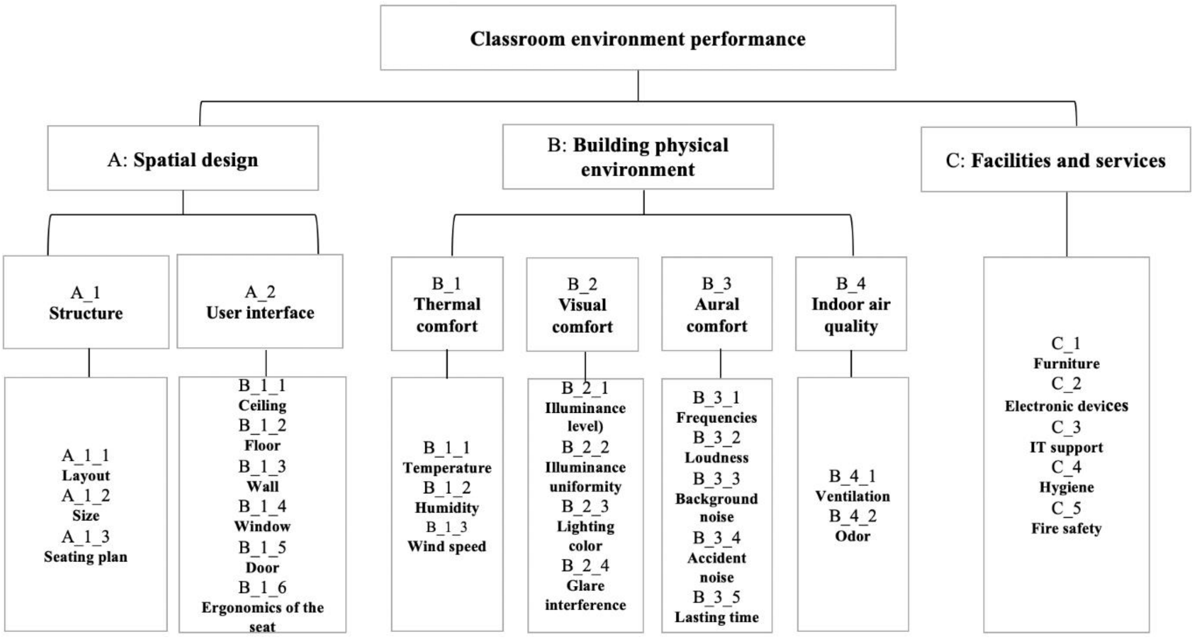
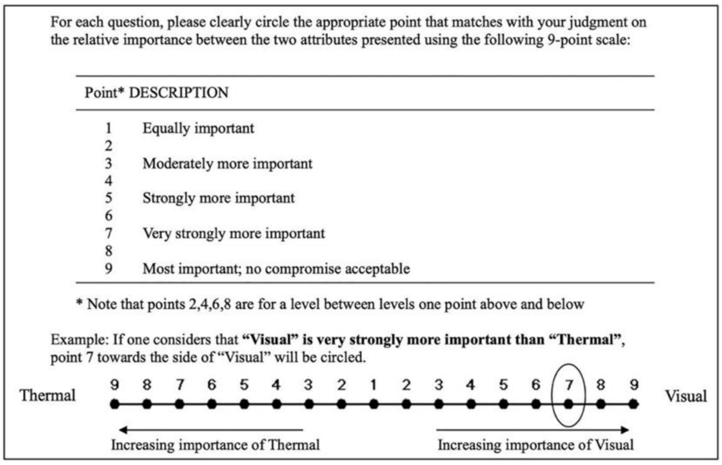


Figure 1 Classroom environment performance assessment framework.

Questionnaire design and distribution based on AHP method

Students with different academic background and education level will be randomly sampling for the survey participation. Instead of approach individual students, the research team will approach instructor from different departments for their support to deliver the questionnaires in their class. During the survey, students will be asked to indicate their perceived importance of the main level and sub-level of classroom IEPs based on an AHP-based questionnaire-survey. Students will be asked to make pairwise comparisons of the indoor environment parameters included in the framework. AHP method is one of the multi-criteria decision-making tools facilitating individual to decide the importance level among multi criteria. As the AHP method gives advantage in mapping out the hierarchical relationships and the interactions among sub-criteria, it is commonly used in decision-making processes that require a high level of fuzzy logic. An example of the pairwise comparison of each pair of indoor environment parameters is illustrated in Figure 2. Students are required to respond to a series of pairwise comparisons of two IEPs or two clusters to be evaluated in terms of their contribution to their particular upper-level criteria. Interdependencies among IEPs of a cluster must be examined pairwise; the influence of each element on other elements can be represented by an eigenvector. The relative importance values are determined with Saaty's 1–9 scale (Figure 2), where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix).


For each question, please clearly circle the appropriate point that matches with your judgment on the relative importance between the two attributes presented using the following 9-point scale:

Point*	DESCRIPTION
1	Equally important
2	
3	Moderately more important
4	
5	Strongly more important
6	
7	Very strongly more important
8	
9	Most important; no compromise acceptable

* Note that points 2,4,6,8 are for a level between levels one point above and below

Example: If one considers that **"Visual" is very strongly more important than "Thermal"**, point 7 towards the side of "Visual" will be circled.

Figure 2 Example of the pairwise comparison between each pair of indoor environment parameters.
AHP method is a quantitative and qualitative decision analysis technique that has been widely used in studies to facilitate decision-making. The AHP, which was first proposed by Saaty (Saaty, 2003), is used to obtain the weighting vectors of the three-level multi-criteria evaluation model.

In this study, the final version of classroom environment performance evaluation framework includes three hierarchical levels. The second step is to establish the pairwise comparison matrix. Under the hierarchical structure, a pairwise comparison matrix can be generated by Equation (1). The next step is to calculate the weighting vectors of each level using Equation (2), wi represents the weighting of each factor. The last step is to test the consistency. The consistency index (CI) and the consistency ratio (CR) are utilized to determine the consistency of pairwise comparisons and the matrix, respectively, as shown in Equation (3). λmax is the eigenvalue; and n represents the number of factors in the pairwise comparison matrix. Generally, CR ≤ 0.1 indicates that the consistency of the pairwise comparison matrix is acceptable.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix},\ a_{ij} = 1/a_{ji}\ (i = 1,2,3,\dots n, \text{and } j = 1,2,3,\dots m) \quad (1)$$

$$W=[w1, w2, \dots, wn],\ w_i = \frac{\sum_{j=1}^{n} \bar{a}_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} \bar{a}_{ij}}, \quad (2)$$

$$CI = \frac{\lambda_{max} - n}{n - 1},\ CR = \frac{CI}{RI} \quad (3)$$

In this study, it was used to solicit students' stated preference between pairs of the aspects of classroom environment parameters based on their experience with the classroom environment. After completing a series of pair-wise comparisons composed by the performance aspects from the evaluation framework, the student's ranking of the performance aspects is obtained, which indicate his / her perception of the performance of the classroom environment.

RESULTS

A number of 288 valid questionnaire were obtained. The students were randomly approached in different classrooms across different buildings in the university. These classrooms are mainly divided into two types: lecture theatre and general classroom. The results of the 288 questionnaire passed the consistency check. The AHP rankings of all the indoor environment parameters are outlined in Table 1. Table 2 illustrates the AHP ranking by groups: gender and classroom types. Students were asked to indicate their gender and the venue they completed the questionnaire survey. Those who stayed in the classroom indicated “classroom” as venue while those who stayed in the “lecture theatre” selected “lecture theatre”.

In Table 1, the weightings and rankings of the performance parameters are structured within a hierarchy, facilitating clear comparisons both within and between levels. Notably, "facilities and services" emerged with the highest importance weighting, accounting for 38.93%, followed closely by "spatial design" and "building physical environment" at 32.25% and 28.83%, respectively. This finding holds significance as it highlights that, despite receiving relatively less attention during the building design and construction phases, "facilities and services" are of utmost importance to the students at the investigated university. This underscores the critical role of post-occupancy operation management. Additionally, it reflects the scientific rigor of the framework development process. Versions 1-3 of the framework did not place "facilities and services" on the same level as other environmental factors, potentially leading to an oversight of the high value students place on this aspect. This underscores students' elevated attention to "facilities and services" in comparison to "spatial design" and "building physical environment. At the second level, the weighting gap values between "structure" and "user interface" are quite similar, with less than a 3% difference. However, students tended to attribute slightly higher importance to "user interface." A similar pattern emerges with parameters such as "indoor air quality," "visual comfort," "thermal comfort," and "acoustic comfort," with "indoor air quality" perceived as slightly more important than the other three. The weightings and rankings serve as direct indicators of students' perceived importance regarding these environmental parameters at each level and category. This information provides valuable insights for facilities managers, offering a concise overview of students' needs and preferences in the classroom environment. It aids in making informed decisions and prioritizing improvements that align with the priorities and expectations of the students.

Table 1 AHP ranking of all the indoor environment parameters.

Hierarchy level	Code	Indoor environment parameters	Weighting	Ranking
Level 1	U_1	Spatial design	32.25%	2
	U_2	Building physical environment	28.83%	3
	U_3	Facilities and services	38.93%	1
Level 2	U_{1_1}	Structure	48.97%	2
	U_{1_2}	User interface	51.03%	1
	U_{2_1}	Thermal comfort	24.94%	3
	U_{2_2}	Visual comfort	25.27%	2
	U_{2_3}	Acoustic comfort	23.82%	4
	U_{2_4}	Indoor air quality	25.97%	1

	U_{3_1}	Furniture	24.55%	1
	U_{3_2}	Electronic devices	15.02%	5
	U_{3_3}	IT support	16.97%	4
	U_{3_4}	Hygiene	19.88%	3
	U_{3_5}	Fire safety	23.58%	2
Level 3	$U_{1\_1\_1}$	Layout	33.55%	2
	$U_{1\_1\_2}$	Size	31.44%	3
	$U_{1\_1\_3}$	Seating plan	36.68%	1
	$U_{2\_2\_1}$	Ceiling	14.34%	5
	$U_{2\_2\_2}$	Floor	14.42%	4
	$U_{2\_2\_3}$	Wall	12.79%	6
	$U_{2\_2\_4}$	Window	18.55%	2
	$U_{2\_2\_5}$	Door	15.50%	3
	$U_{2\_2\_6}$	Ergonomics of the seat	24.39%	1
	$U_{2\_1\_1}$	Temperature	36.12%	2
	$U_{2\_1\_2}$	Humidity	27.74%	3
	$U_{2\_1\_3}$	Wind speed	36.14%	1
	$U_{2\_2\_1}$	Illuminance	21.26%	4
	$U_{2\_2\_2}$	Illuminance uniformity	23.48%	3
	$U_{2\_2\_3}$	Lighting colour	28.16%	1
	$U_{2\_2\_4}$	Glare interference	27.10%	2
	$U_{2\_3\_1}$	Frequencies	20.16%	3
	$U_{2\_3\_2}$	Loudness	17.23%	5
	$U_{2\_3\_3}$	Background noise	18.24%	4
	$U_{2\_3\_4}$	Accident noise	21.94%	2
	$U_{2\_3\_5}$	Lasting time	22.43%	1
	$U_{2\_4\_1}$	Ventilation	50.44%	1
	$U_{2\_4\_2}$	Odor	49.56%	2

The AHP rankings by different gender and different venue (where they completed the survey) reveal certain level of differences in the ranking. For example, male students and female students ranked the parameters under "building physical environment" differently. Another example is that students who stayed in the classroom regarded "fire safety" the most important while those who stayed in the lecture theatre considered "furniture" the most important.

Table 2 AHP ranking of indoor environment parameters by groups (gender; classroom type).

Hierarchy level	Code	Performance attributes	Female		Male		Lecture theatre		General classroom	
			W	R	W	R	W	R	W	R
Level 1	U_1	Spatial design	32.74%	2	31.88%	2	30.77%	2	34.65%	2
	U_2	Building	28.73%	3	29.31%	3	28.29%	3	30.16%	3
	U_3	Facilities and	38.53%	1	38.81%	1	40.94%	1	35.19%	1
Level 2	U_{1_1}	Structure	49.19%	2	48.92%	2	49.76%	2	48.07%	2
	U_{1_2}	User interface	50.81	1	51.08%	1	50.24%	1	51.93%	1

	U2_1 Thermal	25.77%	1	23.62%	3	24.92%	2	25.02%	3
	U2_2 Visual comfort	24.88%	2	25.91%	2	24.73%	3	25.96%	2
	U2_3 Acoustic	24.78%	3	22.33%	4	24.21%	4	22.93%	4
	U2_4 Indoor air	24.57%	4	28.14%	1	26.14%	1	26.08%	1
	U3_1 Furniture	24.02%	1	25.00%	1	26.93%	1	19.50%	3
	U3_2 Electronic	15.49%	5	14.61%	5	14.41%	5	16.13%	5
	U3_3 IT support	17.40%	4	16.73%	4	17.06%	4	17.06%	4
	U3_4 Hygiene	20.01%	3	20.16%	3	19.30%	3	21.32%	2
	U3_5 Fire safety	23.07%	2	23.51%	2	22.30%	2	25.99%	1
Level 3	U1_1_1 Layout	33.43%	2	31.74%	3	32.97%	2	32.03%	3
	U1_1_2 Size	29.97%	3	32.85%	2	30.75%	3	32.41%	2
	U1_1_3 Seating plan	36.59%	1	35.41%	1	36.28%	1	35.56%	1
	U2_2_1 Ceiling	14.55%	5	14.33%	4	14.46%	4	14.42%	5
	U2_2_2 Floor	16.23%	4	12.69%	6	13.43%	5	16.15%	4
	U2_2_3 Wall	12.53%	6	13.21%	5	12.24%	6	13.79%	6
	U2_2_4 Window	19.41%	2	27.77%	1	18.46%	2	17.81%	2
	U2_2_5 Door	16.21%	3	14.87%	3	14.57%	3	16.84%	3
	U2_2_6 Ergonomics of	21.08%	1	17.13%	2	26.83%	1	20.97%	1
	U2_1_1 Temperature	37.34%	1	33.78%	2	37.28%	1	34.68%	2
	U2_1_2 Humidity	27.21%	3	28.41%	3	27.75%	3	27.64%	3
	U2_1_3 Wind speed	35.45%	2	37.81%	1	34.97%	2	37.68%	1
	U2_2_1 Illuminance	20.41%	4	21.88%	3	23.05%	4	19.68%	4
	U2_2_2 Illuminance	24.88%	3	21.83%	4	23.57%	3	23.55%	3
	U2_2_3 Lighting colour	27.82%	1	28.74%	1	26.92%	1	29.32%	1
	U2_2_4 Glare	26.89%	2	27.55%	2	26.46%	2	27.45%	2
	U2_3_1 Frequencies	19.70%	3	20.52%	2	19.51%	3	20.39%	3
	U2_3_2 Loudness	17.87%	5	16.04%	5	16.84%	5	17.91%	4
	U2_3_3 Background	17.95%	4	19.09%	4	18.90%	4	17.67%	5
	U2_3_4 Accident noise	22.79%	1	20.32%	3	21.98%	2	22.09%	1
	U2_3_5 Lasting time	21.69%	2	24.04%	1	22.77%	1	21.95%	2
	U2_4_1 Ventilation	49.40%	2	52.18%	1	48.84%	2	53.20%	1
	U2_4_2 Odor	50.60%	1	47.82%	2	51.16%	1	46.80%	2

The key findings of this study reveal noteworthy differences in perception between male and female students. While the perceptions of "spatial design" (U1), "building physical environment" (U2), and "facilities and services" (U3) are relatively consistent between both genders, significant variations emerge in the second-level categories, specifically concerning "thermal comfort" (U2_1), "visual comfort" (U2_2), "acoustic comfort" (U2_3), and "indoor air quality" (U2_4). Male and female students markedly differ in their views regarding these parameters. Notably, male students attribute greater importance to "indoor air quality" (U2_4) compared to the other three performance measures, whereas female students prioritize "thermal comfort" (U2_1) as the most significant factor. The small weighting gaps among these indicators emphasize the significance of sub-groups within "thermal comfort" (U2_1) and "indoor air quality" (U2_4). Within the sub-group "thermal comfort" (U2_1), which includes "temperature" (U2_1_1), "humidity" (U2_1_2), and "wind speed" (U2_1_3), female students allocate weightings of 37.34%, 27.21%, and 35.45%, respectively, while male students distribute weightings of 33.78%, 28.41%, and 37.81%. This divergence indicates that female students are more concerned about the classroom temperature, while male students exhibit a higher sensitivity to wind speed. Furthermore, within the "indoor air quality" (U2_4) sub-group, female students express a preference for "odor" (U2_4_2) over "ventilation" (U2_4_1), whereas male students prioritize ventilation. This divergence is noteworthy because ventilation significantly impacts wind speed, suggesting that male students are more attuned to airflow in the classroom, while female students are particularly sensitive to temperature. These findings shed light on the differing priorities and sensitivities of male and female students, with females placing a stronger emphasis on temperature, and males being more attentive to airflow. Understanding these nuances in perception is valuable for tailoring classroom environments to better suit the needs and comfort of both genders.

For students from two different types of classrooms, both groups of students regarded "seating plans" (U1_1_3) as the most significant factor. However, students who remained in the lecture theater rated "layout" (U1_1_1) as more significant than "size" (U1_1_2), which contrasts with the perceptions of those in general classrooms. This suggests that students in lecture theaters believe there is ample space, making the "size" of the lecture theater less critical. Another noteworthy finding is that students who remained in the lecture theater considered "temperature" (U2_1_1) the most significant factor, while those in general classrooms prioritized "wind speed" (U1_1_3). This indicates that students in lecture theaters are more temperature-sensitive. Additionally, those in lecture theaters expressed greater concern about "furniture" (U3_1) than "fire safety" (U3_5), while students in general classrooms ranked "fire safety" (U3_5) as the most crucial factor, followed by "hygiene" (U3_4) and "furniture" (U3_1). Moreover, students in lecture theaters assigned a higher rank to "odor" (U2_4_2) than "ventilation" (U2_4_1), whereas those in general classrooms held different priorities. These findings reveal nuanced differences in the perceptions of students based on the type of classroom environment they occupy. Students in lecture theaters appear to prioritize factors like temperature and seating layout, while those in general classrooms place greater importance on factors such as wind speed, fire safety, and ventilation. Understanding these distinctions can inform classroom design and management strategies to better cater to students' needs and preferences.

DISCUSSION AND CONCLUSION

This study makes a significant contribution by employing a systematic grouping approach to extract specific user preferences from a highly homogeneous group of university classroom users. Since the participants in this study all belonged to the same university, they shared a remarkable degree of homogeneity in their attributes. Utilising this systematic grouping method allowed for a nuanced understanding of the specific preference variations among these students. The disparities identified during the series of five focus group discussions were then translated into distinct performance evaluation framework, each tailored to the characteristics and perspectives of the respective student groups.

In the analysis of survey results, commonly utilised grouping criteria such as gender and classroom types were applied to explore inter-group disparities. Although students from different groups. For example, male students prioritised indoor air quality as the most crucial factor, while female students gave precedence to thermal comfort. This finding aligns with prior research on interior environmental quality, which has investigated how males and females perceived indoor thermal conditions differently.

The results provide insights into which aspects of the indoor environment are considered most important by students. This information can guide educational institutions, facility management (FM) professionals, and designers in making informed decisions about resource allocation and improvements. For the FM industry, knowing which parameters hold the highest importance to users can assist in prioritizing maintenance and improvement efforts. Resources can be allocated more efficiently to address areas that have the greatest impact on user satisfaction and well-being. For researchers, understanding the relative importance of different parameters can inform future research directions. It can help identify areas where more in-depth investigation is needed and guide the development of targeted interventions and solutions.

Utilising the developed assessment framework in a case study conducted at a university in Hong Kong, the study uncovered students' perceived importance of classroom environment parameters. The investigation delved into the importance ranking of performance parameters in university classroom across various sub-groups, including gender, and classroom type. The findings of this study will aid facilities managers in gaining a deeper understanding of students' distinct needs and preferences concerning the indoor environment, ultimately facilitating more effective classroom management and improvement tailored to specific user groups.

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Drivers to achieve future-proofed hospital built assets

Pascale, F.[1,2] and Jones, K.[1]

ABSTRACT

Background and aim – The heal thcare sector is a major contributor to carbon emissions. It is also affected by climate change-induced disruptions. Further, the context in which hospitals operate is changing as healthcare delivery evolves to meet changing patient expectations and technological advancements. Bringing these drivers for change together poses major challenges for hospital managers, and not least for facilities managers responsible for a hospital built assets. This paper begins to explore these challenges in the context of a 'future-proofed approach' for the maintenance and upgrade of the healthcare estate.

Methods / Methodology – This paper presents the result of a scoping review undertaken to identify the drivers with the potential to influence the future healthcare estate, and in turn its maintenance and refurbishment strategy.

Results – When developing strategies to create a future-proofed hospital built asset, facilities managers working within the healthcare sector have an important role to play and need to understand the implication drivers, such as changing healthcare delivery, changing users' expectations, SMART technologies, sustainability, and resilience to extreme events, will have on the journeys that the healthcare sector will need to take to achieve its transition without compromising healthcare delivery.

Originality (if applicable) – The paper introduces the first step towards a future-proofed approach to built asset management of hospitals where drivers for change provide the criteria against which transition pathways will be evaluated.

Practical or social implications – The paper discusses the strategic and operational challenges facilities managers will need to address to future-proof the hospital estate.

Type of paper – Full research paper.

KEYWORDS

Hospital built asset, future proofing, sustainability, resilience to climate change.

INTRODUCTION

Climate change is a reality and is bringing considerable changes in climate patterns (IPCC 2023), including more frequent and severe extreme weather events (Jetten et al. 2021). These events in turn place greater demands on healthcare services (e.g., increased demand during heatwaves) and disrupt healthcare supply (e.g., flooding resulting in hospital closure) (WHO 2020). Given the predicted increased frequency of such event in the UK (Slingo, J. 2021), the NHS estate is at risk, especially considering the size and the age of the estate (Short et al. 2014).

[1] School of Engineering & the Built Environment, Anglia Ruskin University, federica.pascale@aru.ac.uk
[2] The Healthcare Improvement Studies Institute, University of Cambridge

"*Climate resilient health care facilities are those that are capable to anticipate, respond to, cope with, recover from and adapt to climate-related shocks and stress, so as to bring ongoing and sustained health care to their target populations, despite an unstable climate"* (WHO 2023). However, there has been no comprehensive assessment of the impact of climate change on healthcare facilities (Guihenneuc et al. 2023), and currently, little consideration is given to adaptation strategies to reduce the vulnerability and risks generated by climate change and to strengthen resilience (WHO 2023). The current NHS approach and the Net Zero Carbon Hospital Standard mainly focuses on mitigation strategies to reduce the impacts of NHS facilities on climate change, whilst consideration of adaptation strategies to reduce the vulnerability and risks generated by climate change and, to strengthen resilience still seem on an embryonic phase (NHS 2021).

Given the role of climate change in health and health inequalities, it is concerning to see that the healthcare sector is a major contributor to carbon emissions, equivalent to 4.4% of global net emissions (Karliner et al. 2020). In England, the 'Delivering a Net Zero National Health Service' Report (NHS England and NHS Improvement 2020) recognises the NHS estate and facilities as one of the greatest areas of opportunity – or challenge – for change if net zero is to be achieved. Some strategies to reduce emissions from hospital estates and facilities include: upgrading lighting across the NHS estate, intervening on air conditioning, cooling, building fabric, space heating, ventilation, using roofs and adjacent ground space for on-site renewable energy and heat generation, purchasing 100% renewable energy, and lowering the carbon footprint from anaesthetic gases by transforming anaesthetic practice. However, the size and the age of the NHS estate is a major challenge when implementing these strategies: the NHS encompasses an estate composed of 330 acute hospital sites and a gross floor area of 18.83 Mm2, with 18% of its estate predating the NHS and 43% being more than 30 years old (Short et al. 2014).

According to WHO (2023) "*building climate resilience at the health facility level requires an understanding of current and projected climate conditions, health system demands (such as population growth, demographic changes) and anticipated health system capacity (such as health workforce, financing, technology adoption, connections with community partners and stakeholders)*". The process of anticipating future events, changes, needs and uses to ensure that a system will not be superseded by the need for future capability in a long lifecycle, through identifying future modifications, is defined as future-proofing (Rehman et al. 2017). The concept of future proofing the NHS estate, and the role that facilities managers should play in the process is not new (OBeirne 2019); however, the scale of the climate change threat and the urgency of acting are. However, facilities management practices show a little attempt to address changing user demands, demographic profiles, and economic challenges (Future Hospital Commission, 2013; Zimlichman, et al. 2019; Memari et al. 2022). In addition, the NHS estate is inflexible, under-utilised, over-specified and planned to accommodate out-of-date practices (King's Fund 2013), and also deteriorating, with a £10.2 billion maintenance backlog in 2022; an 11% increase since 2022/21 (ERIC data from NHS Digital, 2023)

This paper presents the results of an initial scoping study of a project aiming to develop a management framework that integrates mitigation (transition to net-zero) and adaptation (addressing the impacts of existing climate change) strategies into built asset management plans that reflect the changing demands of the hospital built assets. The development of the management framework will adopt a participatory backcasting approach (Quist & Vergragt 2006) to planning, where a desirable (future) vision provides the endpoint of the transition journey and backcasting analysis evaluates alternative transition pathways to achieving the vision. The most desirable pathways will then be integrated into built asset management plans. The scoping study reported in this paper is the first step in establishing the key attributes that will inform the desirable future vision and, as such provides the criteria against which transition pathways will be evaluated. The scoping study sought to identify: the drivers with the potential to influence the future hospital built asset, and in turn the alternative maintenance, refurbishment and design strategies that could influence different transition pathways towards a future sustainable and climate-resilient hospital estate.

RESEARCH METHODOLOGY

A scoping review of peer-reviewed and grey literature on the concept of the hospital of the future was conducted (Evans et al. 2020) via Scopus. Studies were identified by searching literature from January 2002 to date, as this was considered a reasonable length of time to understand future drivers. In addition, reference lists of selected articles were searched for other sources. To ensure specific information relating to the research questions were gathered, studies were included if they focused on future perspectives on hospitals. Studies were excluded if they focused on specific types of hospitals, or specific areas of the hospital, or pre-hospital care, or on staff and support for patients, or presented results of prediction or simulation models. In addition, studies were excluded if they were not available in full text, or in English or were outside the identified search period. Literature reviews, commentaries, and opinion pieces were also excluded. The primary reviewer conducted the search on Scopus and reported the eligible studies in a citation manager tool. A tool to extract the data was designed and constructed by the authors in Microsoft Excel and the main reviewer collected the data in consultation with the second reviewer. The summarisation and reporting of the data used a descriptive approach based on thematic analysis. The Scopus search identified 925 sources that discussed the hospital of the future. A screening of the relevance of the sources by title reduced the number of potentially relevant sources to 224. A further screening of these sources by their abstract reduced the number of relevant sources to 118 which were full articles screened in line with the criteria outlined by Peters et al. (2020) for a scoping review. Full screening resulted in 55 articles included in the scoping review.

RESULTS

The scoping study identified five main drivers, which will need to be considered in built asset management strategies by facility managers to achieve a future-proofed hospital estate: changing healthcare delivery; changing users' expectations; SMART technologies; sustainability; and resilience to extreme events.

Changing healthcare delivery: The way healthcare is provided within the healthcare network and within the hospital itself has profound implications for the healthcare estate. The ideas of changing the role of the hospital within the continuum of care and moving to a community-centred care approach have been consistently reported in the literature since the first decade of the twenty-first century (Francis & Glanville 2001; Umbdenstock et al. 2011; Future Hospital Commission 2013; Ribera et al. 2016, Zimlichman 2019) and has again attracted attention because of responding to the Covid-19 pandemic (Setola et al. 2022). The pandemic has highlighted the need to reconsider the entire healthcare network and the role of the hospital in the healthcare system, as the resilience of each building cannot be separated by the reorganization of the local or regional healthcare system (Setola et al. 2022; WHO 2023). Recent advances in digital technology are also driving a move to a distributed model of healthcare (Zimlichman et al. 2023), where better-connected hospitals, integrated care delivery, hospitals at home, surgery performed in community settings and a larger emphasis on prevention are some of the suggested strategies for the future (Ferrara et al. 2022; Molyneux 2023; Mott MacDonald 2023; Zimlichman et al. 2023; WHO 2023). Within the hospital itself, the care model needs changing, as it should be streamlined around patients' needs (Francis & Glanville 2001; Zajac 2003; The Future Hospital Commission 2013) and, be implemented through a more effective care system, which requires a team approach to care (Umbdenstock, 2014). This may drive a move from hospitals' current structure of departments and specialties to multidisciplinary healthcare areas (Gómez Huelgas et al. 2020; Read 2021; Zimlichman et al. 2023) with spaces capable of supporting a more organised and systematic care process. This includes the provision of clinical and other therapeutic adjacencies to improve clinical and patients flow between different parts of the system (Edwards 2023), and space and layout to foster positive culture and support multidisciplinary working and improve staff well-being and safety (Makram & El-Ashmawy 2022; Edwards 2023; Mott MacDonald 2023; WHO 2023).

Changing users' expectations: Improving patient's experience is also a trend which has emerged through the years (The Future Hospital Commission 2013; Ribera et al. 2016; Meesala & Paul 2019; Cado 2022; Philps 2022). Whilst Ribera et al. (2016) focused on the need to develop programs for patient experience improvement, in recent years the focus has shifted to considering evolving patient expectations (Philps, 2022). Also, the need to support healthcare professionals, which first appeared in the early 2000', remerged in recent years (Francis, S., & Glanville, R. 2001; Zimlichman et al. 2023). These reflect the need to 'develop therapeutic care environments' able to provide positive care experience for patients by placing as much value on the experience and compassion as clinical effectiveness (Future Hospital Commission, 2013). This has also been defined as 'salutogenic architecture' (Golembiewski 2017), which is the need to integrate the therapeutic potential of the environments in the design approach, make buildings that are sensitive to the physical and emotional needs of patients, give reassurance to relatives and friends and express the value that society places on healthcare have appeared in the literature since the early 2000 (Francis & Glanville 2001). Increasing interest has also emerged on the benefits of 'biophilic design', which includes principles such as incorporating nature, green spaces, daylight or sunlight, natural ventilation, and links between the internal and external landscapes (Francis & Glanville 2001; Bulakh et al. 2021; Makram & El-Ashmawy 2022; Edwards 2023; WHO 2023), which are also present in the sustainability agenda. There is an emerging desire for more patient-centric hospitals, where spatial design can support a more personalised, relaxed, and convenient patient hospital experience (Selami Cifter & Cifter 2017; Mott MacDonald 2023), with novel concepts emerging to bring care to the patient, not vice versa (Amato et al. 2022), and involving patients and other key stakeholders in the design process (The Joint Commission 2008; Mott MacDonald 2023). The involvement of patients and staff will be crucial to identify strategies that will also lead to the 'improvement of quality and safety' (Umbdenstock et al. 2011; Zimlichman 2019), in terms of patients and staff experience within the built environment (Francis, S., & Glanville, R. 2001; The Future Hospital Commission 2013; Ribera et al. 2016; Meesala & Paul 2019; Cado 2022; Philps 2022; Zimlichman et al. 2023). However, this will require a multidisciplinary approach to built asset management with new professional figures being brought in to facilitate constructive consultation with patients and staff.

SMART technologies: In the last ten years, the idea of using technology to support a smart healthcare provision has accelerated. While in the first twenty years of the twenty-first century, the focus was on a limited range of technologies, such as smartphone applications (Park et al. 2015), in the last few years, a variety of technologies have started to emerge. Digitalization, telehealth, and mobile health solutions have demonstrated the potential to modify the provision of care both within and outside of the hospital and help hospitals become the "Control Tower of Communities" (Pickering et al. 2012; Hammond 2019; Zimlichman 2019; Gómez Huelgas et al. 2020; Cado 2022; Philips 2022; Rogers et al. 2022; Ndzimakhwe et al. 2023). Artificial Intelligence (AI) and robotic technology have been recognised as diagnostic tools able to improve quality and safety, provide more personalized and more efficient care, help optimize operations, save providers time, enhance efficiency, and improve the patient experience (Hammond 2019; Zimlichman 2019; Horgan et al. 2020; Aung et al. 2021; Cado 2022). Digital technology can also help manage access and flows throughout the hospital with a combination of digital identity, verification of infections and tools for patient tracking, wayfinding, navigation, and self-service (Mott MacDonald 2023; WHO 2023), whilst robots can improve hospital resilience, precision, and efficiency (Taylor et al. 2022; Mott MacDonald 2023). Hospitals are also becoming smarter, intelligent, and equipped with real-time energy monitoring and control. Artificial intelligence can optimise the way that hospital buildings are used to reduce carbon footprint through improving heating, ventilation, air conditioning and/or other infection control processes (NHS 2020, Edwards 2023). From the literature review emerges that the digitalization of built asset management through BIM and other similar tools can support holistic future-proofing objectives and facilitate better informed built asset management decision-making (Krystallis et al. 2016; Koch et al. 2019; Wanigarathna et al. 2019; Akbarzadeh et al. 2021). However, to facilitate the implementation of these technologies in existing hospitals, technological capabilities need to be improved. In (2005), Chyna discussed the need to improve wireless systems to support care flexibility, whilst in (2011) Umbdenstock et al. expanded the concept to the need to develop integrated information systems to support the digital transformation and help hospitals face unprecedented near- and longer-term demand to change. More recently, Kumar et al. (2020) discussed the need for fifth-generation (5G) technology and the requirements of a smart hospital to implement it.

Sustainability: 'Sustainability' has made an appearance in the future hospital literature in the first decade of the twenty-first century. Francis & Glanville (2001) remarked on the need to meet the criteria of 'triple bottom line' objectives in design and construction, whilst the Joint Commission (2008) mentioned the need to incorporate "green" principles in hospital design and construction. The current NHS target focuses mainly on 'becoming net-zero', which aims to reduce carbon and water footprints, and overall energy use (Edwards 2023; Mott MacDonald 2023). In (2020), the NHS published the 'Delivering a 'Net Zero' National Health Service' and identified the need to reduce emissions from hospital estates and facilities as a priority. In 2022, NHS England published the Net Zero Carbon Hospital Standard (2022), which provides a roadmap for reducing operational building energy demands, embodied carbon in construction and the whole life carbon of building elements used within them. However, the concept of 'engineering green hospitals' is broader and incorporates targets for energy consumption, water use, biomedical waste, transport, eventual reuse, or recycling (Kamath et al. 2019; Memari et al. 2022; Edwards 2023). Some of the suggested strategies are greening the roof and walls; using solar panels; utilizing locally sourced building materials; reducing travel and transportation; harvesting rainwater; filtrating and reusing wastewater; and planting trees on the site (Kamath et al. 2019; Bulakh et al. 2020). In addition, mitigating adverse environmental impacts through 'passive architecture' has also been suggested to reduce both embodied and operational carbon, by implementing natural ventilation, sun protection, aerodynamic volumetric, spatial forms, and daylighting (Kamath et al. 2019; Bulakh et al. 2020; Memari et al. 2022).

Resilience to extreme events: The term 'resilience' entered the future hospital literature in (2008) when the Joint Commission referred to it as the need to "*address emergency preparedness, in hospital design and construction*", in most recent years there seems to be a more specific focus on resilience against sudden and temporary disruptive events such as those due to climate change and pandemics (Memari et al. 2022; Mott MacDonald 2023; WHO 2023). However, strategies associated with resilience have been 'redundancy' (Karlsson et al. 2019) or flexibility in capacity (Joint Commission, 2008) with 'master planning strategies' to identify zones for future growth at the site level, and at the building level to have spaces that can be used for the minimum function and arranged in a way that they can be reorganised for future adjustments. However, due to converging data indicating the existence of possible relationships between climate change, environmental pollution, and epidemics/pandemics, such as COVID-19 (Marazziti et al. 2021), there is an increasing demand to expand the scope of resilience of hospitals and adopt the lessons learnt from the Covid-19 pandemic to improve the resilience to the climate emergency (Khojasteh et al. 2022). Some of the lessons learnt from the pandemic will have major implications for hospital facility managers in the transition to net-zero. For example, limiting the flow of patients from outside urban areas into cities, by placing hospitals outside city centres, can limit infection transmission (Capolongo 2020; Mott MacDonalds 2023). However, while placing the hospital outside the city centres will allow the estate to benefit from greater access to and better integration with green spaces, it will also need further consideration in terms of the carbon emissions caused by travelling to and from the hospital. Another lesson that emerged from the Covid-19 pandemic is the need to 'reduce cross-contamination'. Some examples of how this can be achieved are: adopting layout planning able to facilitate social distancing, reducing the number of users for single buildings, maximising the use of individual rooms fully equipped to be converted into double rooms, 'separating flows' in the hospitals from the access points, separating working areas from the main care provision area, designing storage space to minimizing waiting time and transportation (Makram & El-Ashmawy 2022; Marmo et al. 2022; WHO 2023; Mott MacDonald 2023). However, the strategies for reducing cross contamination if not implemented within a new holistic approach to the hospital estate may require an increase of floor area and consequently an increase of carbon footprint. The need to improve flexibility has also emerged from the pandemic. This is in terms of developing design typology characterized by horizontal configurations; designing for architectural, structural, service, and organisational flexibility (Makram & El-Ashmawy 2022); incrementing capacity by creating adaptable internal space and adjacent and out-of-hospital additional spaces such as car parks (Capolongo 2020; Makram & El-Ashmawy 2022; WHO 2023; Mott MacDonald 2023). However, the question still open is how a more flexible estate can be achieved within the restrictions of the existing estate and what the implications are between flexibility and a journey to net-zero and a more climate-resilient estate. Especially considering that it will not be possible to achieve a flexible hospital estate without 'robust utilities' (Joint Commission 2008), which entails designing utility and communication infrastructure capable of expansion and upgrade to offer flexibility.

DISCUSSION

The global healthcare sector is facing major change. In the UK this change is driven by the need to reduce its impact on future climate change whilst adapting to the threats posed by existing climate change. The drivers that emerged from the scoping review have the potential to change and shape what the hospital of the future will look like and, therefore need to constitute the starting point to develop future scenarios and development performance specifications for a sustainable and resilient hospital estate, as summarised in Figure 1.

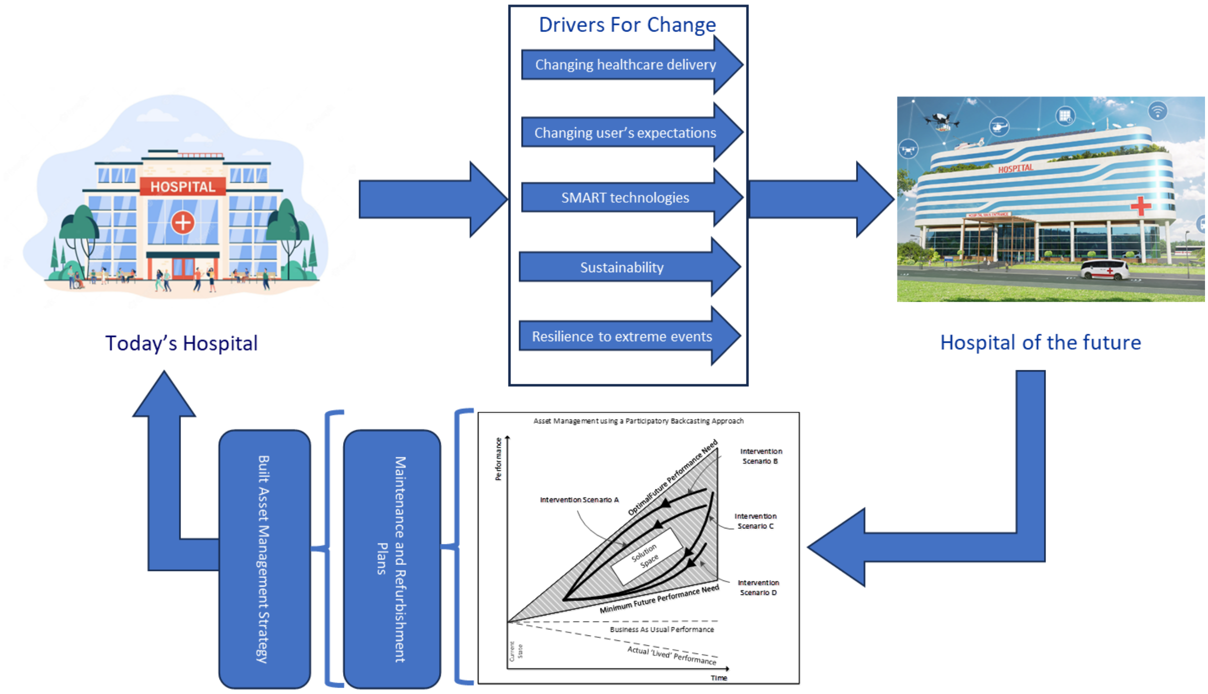

Figure 1 Transition model to the sustainable and resilient hospital of the future. Source of the image of the hospital of the future (European Space Agency, n.d.)

Changing the role of the hospital within the continuum of care and better integrating it with community providers has been advocated since the first decade of the twenty-first century within the literature related to healthcare provision. This trend has also emerged within the literature related to the lasting pandemic impact, which has highlighted the need to reconsider the entire healthcare network and the role of the hospital in the healthcare system. The hospital care model is also undertaking transformations which have remarkable implications from a built environment perspective with hospital care based on process, with multidisciplinary healthcare areas substituting hospitals' current structure of departments and specialities. This calls for a more flexible environment able to accommodate ever-changing care requirements. 'Flexibility' emerges also as a strategic requirement to make hospital environments future-proofed and resilient to future pandemics. The idea that hospital care should be delivered as an inter-connected, distributed system requires the move from a largely centralised, mono-disciplinary model to a distributed, multi-disciplinary model, whilst ensuring no reduction in the quality of care provides the first set of drivers for change to those managing the transition of the hospital estate. When planning strategic intervention to create future-proofed hospital built asset, hospital facility managers will need to consider scenarios on how the shift towards 'care anywhere' or (hospital without walls) will be reflected in hospitals' physical infrastructure which may become more agile, virtual, and spread within the communities. Future strategies for the built environment will need to consider the need to develop a therapeutic care environment able to provide a positive experience to patients and staff through salutogenic design, and biophilic design. The second set of drivers for change will be the need to understand how the increasing user expectation will sit within the net-zero agenda, especially considering the long period of financial instability the healthcare sector has experienced and the need to deal with the realities of healthcare economics (The Joint Commission 2008; Umbdenstock et al. 2011; Umbdenstock 2014; Ribera et al. 2016; Zimlichman et al. 2023). Balancing evolving patient and staff expectations with the new requirement for care and the increasing financial challenges in healthcare will require hospitals to clearly understand their transition journey and define their mission to maintain their competitiveness. The challenges will be clearly felt by facilities managers as they develop business models to justify opex and capex investment in maintenance and refurbishment solutions. The third set of drivers revolves around digital technologies. Large-scale implementation of digital technologies and the increasing roll-out of 5G connectivity within healthcare settings can support hospitals becoming key players, ”Control Towers”, of a smart healthcare delivery system. However, whilst such technologies have the potential to revolutionise how the hospital built environment is planned, designed, operated, and maintained, they will need to be developed at the master planning stage (Mott MacDonald 2023; WHO 2023) to ensure their effective integration across the hospital built assets life cycle. This will involve a more proactive approach being taken to maintenance and refurbishment planning, where decisions are not only informed by immediate need but also by long-term systems upgrade pathways to address changing demands (e.g., future climate change). While current literature provides a clear indication of how to reduce the impacts of healthcare facilities on climate change, with a specific focus on achieving net-zero, little consideration has been provided to the implementation of a more holistic approach to sustainability. The fourth set of drivers will be to understand how to expand the mission of hospitals from beyond net-zero to embracing a holistic sustainability strategy to improve performance not only of new hospitals but also the existing estate and, integrate these strategies in a long-term plan for an estate that may be considerably different in the future. In previous years, resilience has mainly been associated with the concept of redundancy. However, the general failure of healthcare buildings to protect all inhabitants from an infectious disease outbreak during the COVID-19 pandemic (Brusamolin et al. 2020) has highlighted the need to consider resilience from multiple perspectives. The fifth set of drivers for change will be how resilience strategies can be incorporated within a built asset management plan for the existing estate without increasing the estate’s carbon footprint. In considering this challenge facilities managers will need to assess how the hospital built assets will respond to current and future hazard events (e.g., heatwaves) and their associated cascading and interacting impacts (Jones et al. 2023). This will involve facilities managers adopting a systemic approach to modelling hazard risks and developing models that can evaluate how different maintenance and refurbishment options can alleviate or exacerbate the transference of these risks across system boundaries.

CONCLUSIONS

When developing strategies to create a future-proofed hospital built asset, facilities managers working within the healthcare sector have an important role to play. At the strategic level, facilities managers need to understand: the potential impacts that changes to the healthcare provision have on the expectations of those people who use and work in the healthcare sector, and how these expectations will affect the performance of both hospitals and the overall continuum of care from an employee and the customer perspective; and the potential offered by new and emerging technologies to both improve the quality of service delivery and its cost effectiveness. However, the increasing integration of technology will create new stressors for the built environment, which will require a comprehensive technology strategy integrated within the hospital estate lifecycle. At the operational level, facilities managers need to understand the journeys that the healthcare sector will need to take to achieve its transition without compromising healthcare delivery along the journey. These journeys will involve both process evolution (e.g., new ways of providing services, sustainable procurement procedures, etc.) and management of the transition of physical assets (e.g., more flexible use of building spaces, maintenance, and adaptation of technical systems against changing end-user expectations, project management of building transition projects). Whilst these types of challenges are not new to facilities managers, the scale of the challenges is. Facilities managers will need to draw on all their expertise across different business sectors to support the transition to a sustainable and resilient healthcare estate.

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The value building – a conceptual model of circular business models in the building context

Kyrö, R.[1] and Lundgren, R.[1]

ABSTRACT

Background and aim – Circular Economy (CE) aims to reduce consumption by retaining value in the system. While several hierarchical frameworks exist for value retention in general CE, the building context is still missing an established hierarchy. This viewpoint paper outlines a hierarchy of circular business models in the building context.

Methods / Methodology – This viewpoint paper builds on existing knowledge within circularity, lifecycle assessments, and business models. The conceptualization is based on a review of previous literature, including the Authors' own previous work on the topic.

Results – We propose a 'value building', a circular business model hierarchy for buildings. The highest value retention is in the core of the building, with optimal use, maintenance, and minor repairs. The greatest value loss is on the outer layer of the building, with deconstruction and recycling building materials. Outside the building, value may be added to the system through e.g., extensions, but priority should be given to retaining value in the system.

Originality – This paper is unique in outlining a hierarchy for circularity in the building context. It lays a foundation for further assessment of the environmental impact of the circular business models positioned on different layers of the model.

Practical or social implications – Business models with high value retention include minor repairs and maintenance, and redistribution of space (sharing, multifunctionality), which are typically under the control of facility managers. The model works as inspiration and guidance FM professionals aiming to implement circularity in their role and justifying approaches to their clients.

Type of paper – Full viewpoint paper.

KEYWORDS

Business models, circularity, lifecycle, optimal use, value retention.

INTRODUCTION

In a world with finite resources, Circular Economy challenges the linear economy model of make-use-dispose and attempts to keep resources in the system through looping (EMF 2014; EC 2020; Geissdoerfer et al., 2017; Kirchherr et al., 2017). A major strain on resources, the built environment, accounts for 50% of material use, 35% of waste (EC, 2020), 40% of energy use (BPIE, 2011), and 25-40% of carbon dioxide emissions globally (WEF, 2016). Consequently, how buildings are constructed, developed, managed, and used plays a crucial role in the future of our planet. This is particularly important when the forces of change in the external environment cause functional (changing operations

[1] Lund University, Department of Technology and Society, contact: riikka.kyro@lth.lu.se

due to e.g., digitalization, pandemics) or locational (decommissioning due to, e.g., globalization, urbanization) obsolescence in buildings.

Despite the popularity of the concept, circular economy research, practice, and policy are not always focusing on the most efficient measures (Reike et al., 2018; Ranta et al., 2018; Morseletto, 2020). Reike et al. (2018) propose that the effectiveness of circular economy measures depends on loop size, where the shorter the loop, the more efficient the measure. The most effective measures reduce demand and optimise useful life with the least intervention, for example though sharing of assets. Medium loop measures, such as refurbishment or repurposing of a product, require some intervention and are somewhat efficient. The least effective measures, such as recycling, keep the material in the loop, however, dismantling the product causes significant energy consumption and consequent value loss (Reike et al., 2018). Regardless, Ranta et al. (2018) note that recycling is more likely to be implemented by organizations than reusing or reducing, because it has less impact on the business.

To be able to make informed decisions about in which circular activities to engage, organizations would need information about the environmental efficacy and economic implications of different circular measures. Morseletto (2020) notes that most targets applied in circular economy relate to recycling and recovery, while more focus should be placed on creating targets for more effective circular measures which retain value (Morseletto, 2020). The situation is similar in the building context. Abundant research and initiatives focus on the recycling of building material and components to new uses (Pomponi & Moncaster, 2017; Eberhardt et al., 2022). Deschamps et al. (2018) note that open loop recycling has received the most attention, despite being the least effective of all circular measures. Less focus has been placed on business models focused on the possibilities of retaining value that has already been created, tied to the existing building stock.

Achterberg et al. (2016) introduce a value hill model as a hierarchy for circular business models and suggest adapting and complementing the model with context specific knowledge. Accordingly, this paper aims to outline the preferred hierarchy of circular business models in the building context. Following Achterberg et al. (2016), the hierarchy is based on how well value is retained in the system. We will build on existing knowledge within circularity, adaptability, lifecycle assessments, and business models, particularly in the building context. The conceptualization is based on a review of previous literature, including the Authors' own previous work on the topic.

The paper is structured, as follows. The next section first presents existing literature on circular business models and assessments, including the original model this paper builds on, before moving focus on the built environment context. The following section then introduces the adapted model, the value building. Finally, a section detailing the conclusions, contribution, and future research needs, ends the paper.

CIRCULAR BUSINESS MODELS AND ASSESSMENT

Sustainable business models deliver value, not only economic return to the business, but also value to the environment and society (Boons & Lüdeke-Freund, 2013). Bocken et al. (2014) introduce sustainable business model archetypes which include maximizing material productivity and energy efficiency, creating value from waste, substituting with renewables and natural processes, delivering functionality rather than ownership, adopting a stewardship role, encouraging sufficiency, re-purposing the business for society or the environment, and developing scale-up solutions. Several of these may also be considered circular, including creating value from waste, delivering functionality rather than ownership, and encouraging sufficiency. Access-based consumption, as defined by Bardhi & Eckart (2012), and other sharing business models. align with both the value from waste and the functionality over ownership archetype. Sharing business models and are perhaps the most common type of circular business model. Circular business models aim to loop, or retain, value which has been already created in the system (Geissdoerfer et al., 2020). Therefore, by definition, the assets to be shared should be already existing (Curtis and Mont, 2020).

Manninen et al. (2018) called for the assessment of the environmental value propositions of circular business models. Lifecycle assessment is a typical way to assess the effectiveness of circular economy initiatives or projects (Ghisellini et al., 2018). Recent advancements have been made in the lifecycle assessment of circular business models (Bauman et al. 2022; Böcken et al. 2023). Baumann et al. (2022) suggest that businesses should engage in business model lifecycle assessment, similarly as they evaluate the economic profitability. The aim is to introduce lifecycle thinking into business planning and development, and consider the lifecycle sustainability of the business case, instead of an individual product or project. Böcken et al. (2022) put the idea into action and calculate the lifecycle greenhouse gas (GHG) emissions of two different types of business models. The findings suggest that a circular business model, represented by a clothing rental model, is indeed better in terms of GHG emissions than a traditional, linear business model (Böcken et al. 2022).

Lifecycle thinking is crucial in the assessment of environmental sustainability in the building context. Particularly the lifecycle assessment of GHG emissions and energy consumption are common practice (Andersen et al. 2022, Larsen et al. 2022). Lifecycle assessment for buildings most often follow the standard for the sustainability of construction works and services (EN 15804) related to the ISO standard 14044:2006. Typically, the lifecycle stages presented in Figure 1 are employed to define the scope of assessment. We make use of the standard lifecycle modules and link circular solutions from the built environment to the stage of the building lifecycle.

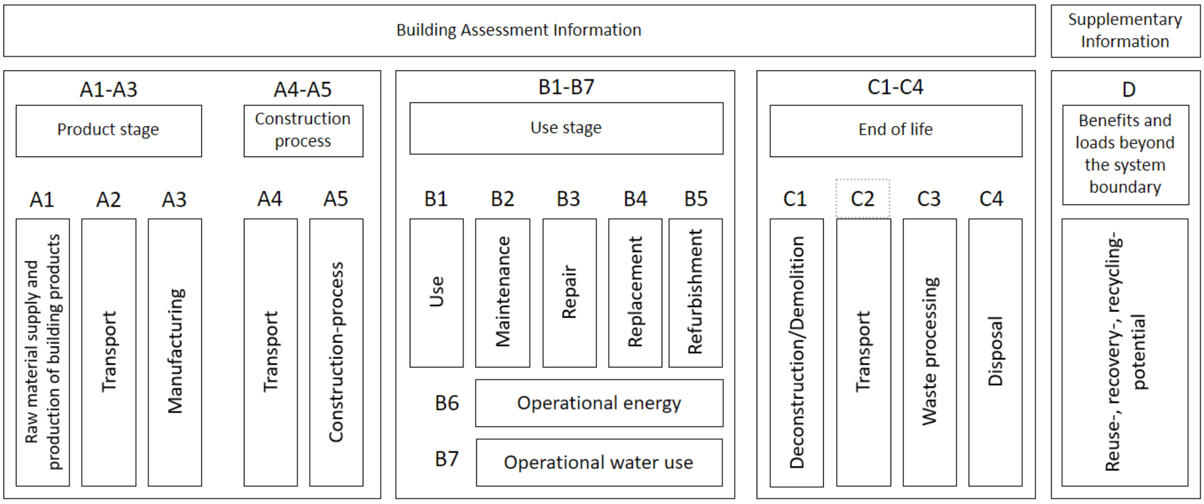
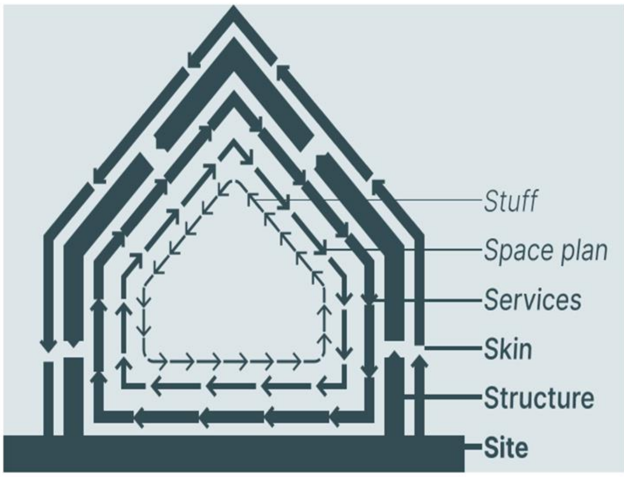


Figure 1 Building lifecycle (adapted from EN 15804).

Brand (1994) introduced already three decades ago the shearing layers of change, see Figure 2a. According to the so-called 6Ss model, most changes should happen in the inner layers. The core layer, which Brand referred to as 'Stuff' has the shortest lifecycles, and includes the interior design and fittings. The following layer is 'Space plan' with a lifecycle of few to less than ten years, followed by 'Services' with a lifecycle of around 10 to 15 years, 'Skin' with the lifecycle of 50 years, and 'Structure' with several centuries of lifecycle. Brand (1994) also includes 'Site' in the layers, pointing out that this layer is eternal. Changes in the structure of the building with the longest lifecycle, should be avoided for as much as possible. Kyrö et al. (2019a) introduced a model for building adaptation based on building system lifecycles, suggesting that several minor changes in the system with the shortest lifecycle, would result in less changes needed in the systems with the longest lifecycle, i.e., the building structure.

Although the concept of loop sizes (e.g., Reike et al. 2018) was not widely established in the 1990s, the same underlying idea can be seen in Brand's model. It is worth noting, though, that the two outer S layers are not closed loops (see Figure 2a).



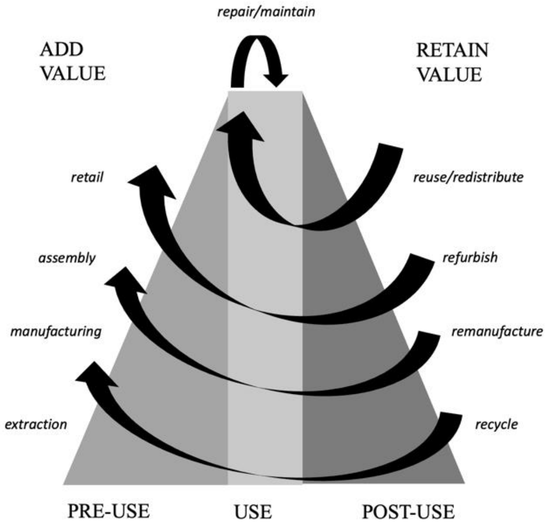


Figure 2a (left) The S layers. Recreated from Brand (1994) by Unknown Author, licensed under CC BY
Figure 2b (right) The value hill. Recreated from Achterberg et al. (2018) by the Authors

Achterberg, et al. (2016) introduce a value hill, which shows either the added value or retained value of different circular business models, see Figure 2b. The higher up on the value hill the model is situated, the less value is lost in the system, i.e., the more value is added or retained. Achterberg et al. (2016) categorize the business models in pre-use, use, and post-use phases, as follows:

Pre-use circular business models. The pre-use business models are about adding value to the system. Extraction incudes sourcing recycled material and components, as well as sourcing low impact materials. One step higher in the model is manufacturing business models, followed by the preassembly of products. Finally, an efficient way to create value are the business models based on sales of products. This phase can limit the resources enter the system through circular thinking and design.

Use phase circular business models*.* The use phase business models are about optimal use. Value is looped in through maintenance and repair of, or services related to the product. For example, sharing business models are part of this category. The loop, as described by Reike et al. (2018) is very short, and value loss is insignificant. This is the optimal way to retain value once the resource has been introduced to in the system.

Post-use circular business models. The post-use business models are about value recovery. Illustrated as a declining hill, value retention gets weaker with every step, starting from reuse or redistribution, which still maintain a rather short loop. Refurbishment and remanufacturing are connected to medium to medium long loops (Reike et al. 2018). The least beneficial business models, which may still be considered circular, relate to the recycling of components or materials from the product, well aligned with Reike et al. (2018) idea of inefficient long loops.

THE VALUE BUILDING

We take inspiration from the value hill framework by Achterberg et al. (2016), the sheering S layers in the model by Brand (1994), and loop sizes by Reike et al (2018). We further use existing knowledge on the lifecycle and environmental assessment in the circular economy in general, and of buildings in particular, to develop the 'value building'.

It should be noted that a building lifecycle, especially the end-of-life, differs significantly in complexity compared to most other products. A building is normally considered to reach its technical end-of-life at 50 years, yet many buildings survive much longer than the technical lifecycle, often several hundreds of years. Meanwhile, several sub-systems reach the calculated end-of-life significantly sooner, starting from 5-15 years. Moreover, buildings are refurbished, retrofitted, and renovated for economic, functional, or even aesthetic reasons before the end-of-life of the building or it's sub-parts. More viable alternatives exist for buildings at the end-of-life of the various building systems and components, than perhaps other products. Consequently, the Pre-Use, In Use, and Post-Use phases of a building are tangled, and their relationship more complex than with e.g., consumables. However, to develop a conceptualization, we consider the Pre-use phase corresponds to lifecycle module A: Product stage and construction process, the In-use phase corresponds to lifecycle module B: Use stage, and the Post-Use phase corresponds to module B: Use stage, module C: End-of-life, and even module D: Benefits and loads beyond the system boundary (refer to Figure 1).

Adding value to the system through the product stage and construction process

Circular extraction. Salvaging and recycling building components and materials is considered a circular business model, perhaps the best-known and most researched example in the field. However, circular extraction is considered a less-effective, long loop measure, as a lot of energy is used, and value is lost in the process. Indeed, circular extraction through recycling has been named the least efficient measure still considered circular (Deschamps et al., 2018) **The value adding potential is minor.**

Circular construction. New construction with circular materials and components, and design-for-disassembly (DfD), are likewise commonly highlighted circular business models. Yet, also these are a less effective measures due to their long loop size. What is more, DfD is focused on keeping the material and energy in the system in the future, while there is an urgency to cut down materials use, embodied energy, and carbon emissions to reach circularity now. **The value adding potential is minor.**

Extension. A more efficient way to introduce circularity to the construction practice would be to extend existing buildings vertically (Sundling et al. 2019), or horizontally through infill development. That way, even though new construction is needed, the resources tied to both the existing building, as well as the existing infrastructure onsite, are kept in the system. **The value adding potential is moderate.**

Modularity. Assembly in the building context translates into prefabrication and modularity. Prefabrication and modularity have been found to be more environmentally sound, as they save resources in terms of time, energy, and transport (Nahmens & Ikuma 2012; Quales et al. 2012).

Modularity also links to circularity in that allows for simple dismantling, maintenance, and reuse of components (Minunno et al. 2020). **The value adding potential is moderate.**

Optimizing use during the use stage

Transactions. In the building sector transactions are a central business model to add value, and unlike some other industries, rental models have been in place for centuries. Therefore, variations that would be considered circular in this context include more flexibility in lease agreements and shorter-term, even pay-per-use access. The servitization of spaces and space-as-a-service business models have also gained foothold in recent years (Petrulaitiene et al. 2018). Services that aim for the optimal use of buildings may contribute to reducing the overall demand for space. In terms of Brand's (1994) layers, this category would often incur changes to the inner Space plan layer, and in terms of loops sizes, rental and other transactions of existing assets are a short loop measure. It should be noted, however, that the frequency and scope of adjustments, such as tenant fitouts, may result in significant value loss. **The value retention potential is major.**

Maintenance and minor repair. Value in the system is best retained through optimal use throughout a product's useful life, and business models like repair and maintenance of products. In the building context, due to the long lifecycles of buildings, maintenance and minor repairs are standard practice, however, rarely acknowledged as circular business models. Nevertheless, analogous to other fields, building maintenance improves durability, extend the building's useful life, and may result in less input into the system (Ness & Xing, 2017). Repair and maintenance are typical short loop measures in general circularity literature (Reike et al. 2018). **The value retention potential is major.**

Sharing. A well-established circular strategy to reach optimal use, and potentially reduce demand, is sharing. Sharing in the building context takes the form of shared spaces (Lundgren et al. 2022). Sharing spaces can improve space efficiency (Francart et al., 2020) either by increasing the utilization rate of the area, or the time that it is used (Höjer & Mjörnell, 2018). Brinkø and Nielsen (2017) suggest several motivators for sharing spaces, namely, optimizing use of square meters, cost reduction, synergies, sustainability, and flexibility in the portfolio. In addition to simultaneous sharing, temporal variants of shared spaces such as, multifunctionality or temporary use, are ways to retain value in the existing building stock. Like Transactions, this category links to the Space plan layer of Brand's (1994) model and is a short loop measure. The intrusiveness to the building is typically low (Kyrö, 2020b), yet, like Transactions, caution needs to be taken when adapting the space plan not to lose value. **The value retention potential is major.**

Retaining value during use, end-of-life, and beyond

Refurbishment. Renovation with low intervention, such as, energy retrofits, or replacing building systems at end-of-life, are considered medium loop circular business models. In Brand's (1994) terminology, these are the changes to the layer Services. Renovation is typically more beneficial to the environment than new construction due the embodied impact of new construction (Ibn-Mohammed et al. 2013; Pomponi & Moncaster, 2016; Vilches et al. 2017; Yung & Chang, 2012; Zimmermann et al.

2023). Refurbishment may also reduce operational energy because of energy saving measures introduced in the renovation (Ibn-Mohammed et al. 2013). However, Jerome et al. (2022) find that an extensive renovation does have a long payback time, especially in monetary terms, but also in terms of carbon emissions. In other words, the less intervention required, the more value is retained. **The value retention potential is moderate.**

Adaptive reuse. Repurposing a product to a new use, a typical medium loop circular measure, translates to adaptive reuse in the building context. More intervention is required, and more value lost in the process compared to a minor renovation. Yet, adaptive reuse is environmentally more sustainable than new construction, and considered a key measure towards circular economy (Conejos et al.; Foster & Kreinin 2020; Foster et al. 2020). Adaptive reuse reduces embodied carbon significantly, when the building structure, containing the most embodied energy and carbon, is saved (Itard & Klunder, 2017; Sanchez et al. 2019). Adaptive reuse may also enable more optimized building use, which may justify the intrusiveness of the measures (Munarim & Ghisi, 2016; Lundgren et al., 2023). Depending on the extent of the adaptation, the layer in Brand's (1994) category would be either Skin or even Structure, in addition to adaptation of Services and Space plan. **The value retention potential is moderate.**

Relocation. Relocating an existing building to a new location is an interesting value retaining business model. Kyrö (2020b) notes that relocaton requires a major paradigm change, as well as a major intervention to the physical building. However, transferable building modules are an example that this business model already exists and even thrives in some uses, such as schools, daycares, and healthcare (Kyrö et al. 2019b; Edelman et al. 2016). Relocating is challenging the idea that Brand's (1994) seventh layer*, Site,* is eternal, in the context of the building lifecycle. Kyrö et al. (2019b) describe relocation as an embodiment of circularity, essentially 'looping' the entire building. Due to the intrusiveness of the measure, relocation may be considered a long loop measure, where the building is at the end-of-life stage, before gaining new life at another location. Yet, significant amount or embodied energy, GHG emissions, and materials could be saved through relocation, depending on how much of the building is kept intact. **The value retention potential is moderate.**

Deconstruction. Demolishing a building occurs in the actual Post-use phase in the building context, covering the end-of-life stage and building lifecycle module C. The intrusiveness has reached the Structure layer in Brand's (1994) model. In cases where demolition includes the salvaging of materials, components, and fittings, the act is called deconstruction. Deconstruction may still be considered a circular business model, although the value loss of this long loop measure is significant. **The value retention potential is minor.**

Recycling. Recycling salvaged building materials, components, and fittings to new construction, instead of the landfill or incineration, is a well-known circular business model. Different types of platforms, marketplaces, and circular material banks have gained popularity in the field in recent years. Nevertheless, recycling is considered the least effective measure in all circular economy hierarchies, including the basic waste hierarchy. **The value retention potential is minor.**

Summary

Table 1 presents a summary of the circular business models in the building context with their value creation or retention potential as detailed in the previous sub-section. The table also links the business models to the respective sheering layers (Brand, 1994), lifecycle modules (*EN 15804, see Figure 1*), and loop sizes (Reike et al., 2018).

Table 1 Circular business model categories in the built environment.

Category	Value	Layer	Lifecycle	Loop size
Circular extraction	Minor	All	A1-A2	Long
Circular construction	Minor	Structure	A3-A5	Long
Extension	Moderate	Structure	A3-A5	Medium
Modularity	Moderate	Skin, Services	A3-A4	Medium
Transactions	Major	Stuff, Space plan	n/a	Short
Maintenance and repair	Major	All	B2-B3	Short
Sharing	Major	Stuff, Space plan	B1; B6-B7	Short
Refurbishment	Moderate	Skin, Services	B4-B5	Medium
Adaptive reuse	Moderate	Skin	C1-C4	Medium
Relocation	Moderate	Site	n/a	Medium
Deconstruction	Minor	Structure	C1-C3	Long
Recycling	Minor	All	C3; D	Long

Figure 3 visualizes a circular value hierarchy for buildings. The highest value retention and smallest loop is in the core of building, with business models aiming to reduce overall demand of space through optimal use. These include Maintenance and minor repair, Sharing including multifunctionality, as well as Transactions, including space-as-a-service and flexible leases. The middle layer retains value in the system through business models related to Refurbishment, such as retrofitting, and renovations, as well as Adaptive reuse. Modularity and Relocation are also be connected to this layer and a medium loop. The greatest value loss is found outer layer, with the business models related to Circular extraction and construction in the pre-use phase, and Deconstruction and Recycling in the post-use phase, with only minor potential for value retention. Outside the building, value may be added to the system through vertical or horizontal Extension.

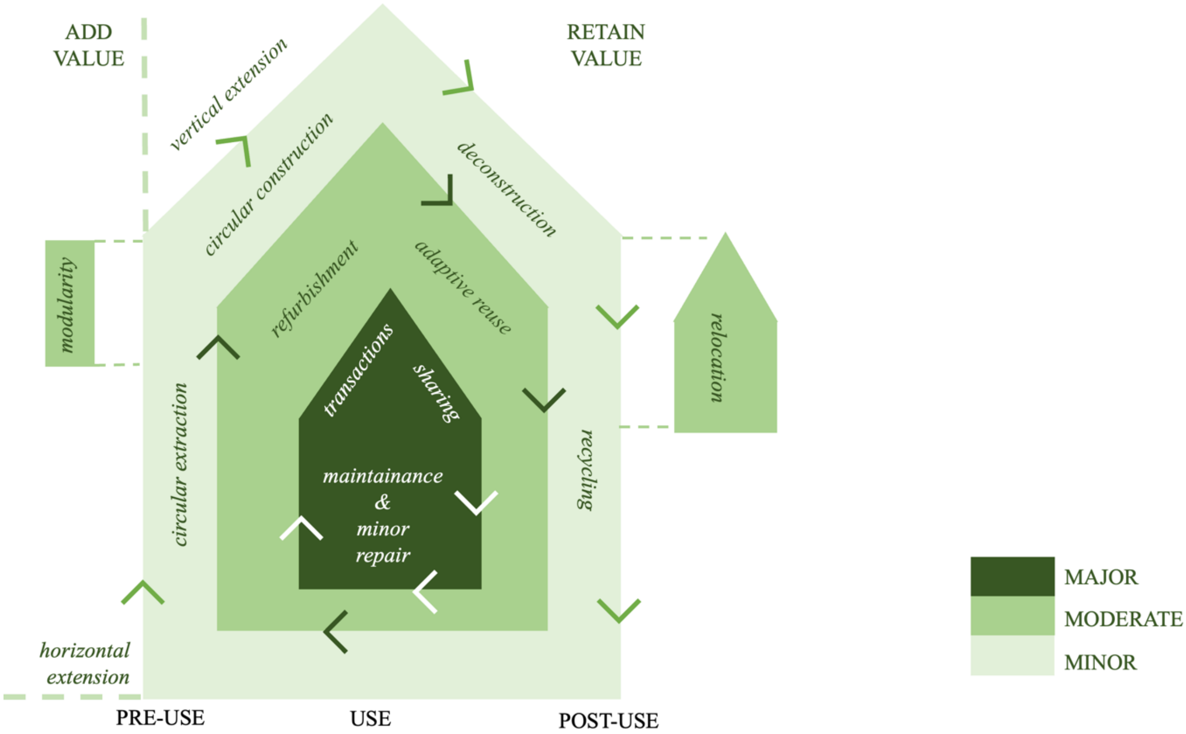


Figure 3 The value building.

DISCUSSION, CONCLUSIONS, AND FUTURE PATHS

As per the aim, this paper outlines and prioritizes circular business models in the building context, including different ways to respond to both functional and locational obsolescence. It provides a novel conceptualization of circularity and lays a foundation for further assessment of the economic, environmental, and social impact of circular business models on different levels of the hierarchy. When adapting the original value hill framework, several modifications were necessary to fit the nature of the building sector, particularly long lifecycles, and entangled lifecycle phases. Buildings characteristically have longer use phases before the final end-of-life stage, and more viable options for prolonging the lifecycle. Furthermore, maintaining and repairing buildings is and has always been commonplace, although not always seen as a circular, value retaining measure. Finally, buildings have been the subject of traditional rental models for centuries. However, the rental models referred to in our model, allow shorter term access or functionality rather than long-term ownership-like rental agreements. It could be argued that buildings are inherently more circular than many other products. On the other hand, also the environmental impact is unparalleled, making the transition to circularity necessary.

Business models with high value retention, such as, minor repair and maintenance, or sharing and multifunctionality, are typically under the control of facility managers. The hierarchy will therefore be useful to FM practitioners aiming to implement circularity in their roles. Encouragingly, the highest value retaining measures, are also the ones with the least intervention and resources needed. Prudent maintenance and minor repair, as well as the sharing of space between different uses and users, are already existing practice in the FM field. Experimenting with circular business models such as shared spaces or pay-per-use services in individual buildings should be feasible. Based on the experiences, a scale up through e.g., the portfolio of a client organization, may be possible.

Morseletto (2020) points out that the most important strategy in transitioning to a truly circular economy is to rethink, which requires innovation and open mindedness. Kyrö (2020) suggests that for example digitalization could offer novel possibilities in terms of circularity.

Lundgren (2023) suggest that environmental impacts, economic profitability, and social aspects should all be included for business model assessments in the building context. While the 'value building' focuses on retaining value that has already been created in economic and environmental terms, further versions should attempt to incorporate social perspectives. Moreover, despite the foundation in existing knowledge, the 'value building' as presented here remains a conceptual model. The Authors plan to further refine and validate the model with input from experts in the field, as well as comprehensive lifecycle assessments (lifecycle assessment, lifecycle profit, and social lifecycle assessment) of the value retaining business models.

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The case for a paradigm shift in providing and managing UK public sector assets based on integrating sustainability principles

Keith Jones[1] and Ronan O'Hara[2]

ABSTRACT

Background and aim - The built environment's contribution to climate change is well understood across the built environment professions. Whilst numerous technical solutions exist to reduce the impact of existing and new buildings on greenhouse gas emissions (mitigation) and manage the impact of climate change on society (adaptation), the uptake of solutions across existing portfolios is slow and fragmented. Why do we as managers of the built environment continue to pursue asset management activities that only partially address sustainability policy objectives? This paper explores the relationship between built asset management in the UK public sector, delivering net zero outcomes and investment planning activities, to suggest an alternative conceptual construct for delivering a sustainable public estate.

Methods / Methodology - The paper presents a literature review covering existing theory, UK policy and professional practice as well as drawing from the lead author's involvement in developing the 3rd edition of the RICS public sector asset management guidance.

Results - The paper identifies a gap in knowledge associated with capital investment planning and translating policy objectives into sustainable asset management outcomes. The paper points to the need for a paradigm shift within public sector asset management, and specifically the approach to capital investment planning, to improve the long-term sustainability of the public estate.

Originality - The paper presents a challenging perspective on asset management and the role of capital investment planning in achieving a sustainable public estate.

Practical implications - Improved sustainability of built assets.

Type of Paper – Full Viewpoint Paper

KEYWORDS

Climate action, sustainability, net zero, asset management, backlogs, capital investment planning, UK public sector.

INTRODUCTION

Buildings account for 39% of global carbon emissions, decarbonising the sector is one of the most cost-effective ways to mitigate climate breakdown, with embodied carbon contributing 11% of all global emissions (World Green Buildings Council, 2019). The UK Public Sector underinvests in existing assets (Department of Education, 2021., NHS ERIC, 2021). The public sector routinely provides built assets and then fails to maintain them, resulting in investment backlogs. Underinvestment in existing assets drives financial inefficiencies and premature obsolescence, with late investment costing more than investment

[1] Anglia Ruskin University, UK. Corresponding Author Keith Jones (keith.jones@aru.ac.uk)
[2] Anglia Ruskin University, UK. Corresponding Author Ronan O'Hara (rpo113@aru.ac.uk)

made at the optimum time (Kaganova, 2011., and HM Treasury, 2020). Underinvestment depresses growth, as depletion of public capital stocks raises costs for the private sector, and overall fiscal consolidation is less likely to be successful if it relies on cuts in public investment (Percoco, 2011). Existing built asset stocks are an important physical, economic, social and cultural capital to any nation (Kohler and Yang, 2007).

The World Conference in Rio de Janeiro (1992) recognised that existing production and consumption systems will lead to a global catastrophe. The current approach to producing and consuming built assets in the UK, and the associated underinvestment in maintenance, is inconsistent with sustainability theory (Our Common Future, 1987). Saeed and Shafqat (2017) explain that sustainable asset provision "…involves conceiving, designing, constructing, operating, maintaining, and when needed, repairing and rehabilitating the existing infrastructure". An argument exists to suggest the public sector should not build more than it can afford to maintain, thereby delivering "…development that meets the needs of the present without compromising the ability of future generations to meet their needs" (Our Common Future, 1987).

Attempts have been made to integrate sustainability principles into asset management models (Maletič, Maletič, Al-Najjar and Gomišček, 2018). Commonly cited difficulties include conflicting priorities from top management, short termism, education gaps and resistance to change (Woodhouse, 2003). The uncertainty associated with climate change, the long-term nature of climatic projections; and the short-term operational demands arising from buildings make it difficult for facilities managers to prioritise climate change over other interventions that have a more immediate benefit (Desai and Jones, 2010). Traditional maintenance is still very much the norm, and although the sustainability agenda is considered important, it is not routinely integrated within asset planning (Cooper, 2015).

The context for the proposed research is the sustainable provision and management of the public sector estate. The lead author has 20+ years' experience managing public sector portfolios throughout the UK and contributed to asset management guidance published by the Royal Institution of Chartered Surveyors (RICS) and the Northern Ireland Audit Office (NIAO). As a practitioner he has observed a dissonance between recommended asset management practices (what we say we should do - espoused theory) and operational reality (what we do in practice – theory in use), a phenomenon recognised in the work of Malekpour et al (2017) and Argyris and Schon (1974).

The key goal of this paper is to deliver a structured review of the existing research and grey literature relating to built asset management, to understand better why managers of the built environment in the UK public sector pursue investment and expenditure activities that only partially address sustainability policy objectives. The relationship between facilities management and asset management is illustrated in Annex A, demonstrating the relevance of the research to the facilities management community.

While this study is positioned among many others devoted to the topic of sustainability in the built environment, we add to this body of existing work by considering the role of long-term capital investment planning which is distinct from annual budgeting. The originality of our study stems from the fact existing studies typically promote a project, technical, building or programme perspective. Our key contribution is: (1) demonstrating that the literature reviewed is largely silent on long-term capital investment planning, suggesting a gap in research, (2) drawing attention to the opportunity for public services to be less reliant on built assets, thereby reducing long-term liabilities and improving the sustainable provision of public sector assets, and (3) introducing the concept that asset provision should be capped based on the affordability of whole life costs to force a sustainable dynamic, or alternatively financial reserves are introduced (sinking funds), or costs recovered to service long-term asset liabilities.

As such, the paper contributes to creating a broad composite analysis of existing research and grey literature, indicating areas of underdeveloped research and opportunities for future research.

RESEARCH METHODOLOGY AND DATA

A comprehensive literature review was conducted with the aim of considering an overarching primary research question…, what can literature tell us about why managers of the built environment continue to pursue investment and expenditure activities that only partially address sustainability policy objectives? A hybrid research methodology based upon digital library searches and backwards snowballing was adopted (Mourão, E., et al 2020). Conditions for initially selecting papers were based on research relevance including title, subject, abstract and key words. Full details of the methodology used, and the journals accessed can be read in Annex B and Annex C.

Separately a targeted review of grey literature was conducted, focused on material from professional bodies and UK public bodies. Grey literature was deemed appropriate and value adding, as the lead author is working towards a Professional Doctorate. Research associated with a Professional Doctorate should create knowledge which relates to everyday practice (Jamieson and Naidoo, 2007., Fenge, L. 2009) and grey literature can help bridge between everyday practice, policy, and research.

The information, data and insights gathered was then used to address four secondary research questions (RQs):

RQ 1. What is the UK Policy context for public sector asset management?
RQ 2. How has the nature of Asset Management professional practice evolved in the UK?
RQ 3. What is the relationship between Asset Management and Sustainability?
RQ 4. What is the relationship between capital investment planning and built asset management?

In answering the primary and secondary research questions, consideration was given to the case for a new paradigm in providing and managing public sector assets. Insights derived from the literature review and analysis process included the challenges and opportunities associated with integrating sustainability principles into UK public sector asset management practices and the critical role of capital investment planning. In the round these considerations support the general case for a new paradigm.

LITERATURE STUDY

RQ 1. What is the UK Policy Context for Public Sector Asset Management?

In the 1980s, the public sector was reportedly ahead of the private sector in terms of the proactive management of real estate (Ramidus Consulting Limited, 2010). Reports by Davies (1982) and Gowrie (1985) on the NHS and government office portfolio highlight the opportunities associated with the management of public sector assets. Avis, Gibson & Watt (1989) conclude that management demonstrate '...*a lack of understanding of the role of property and little knowledge of the contribution it makes to the organisation'*. By the turn of the millennium, a rationale for progressive approaches to the use and management of property assets had been established across the UK public sector. In the 2000's, separate reports by Gershon (2004) and Lyons (2004) argue for better management of public sector assets and an improved efficiency in asset management. In April 2009 the HM Treasury launched an Operational Efficiency Programme (OEP), which concluded there is significant scope for public sector property and land to be managed more efficiently and effectively. Throughout the period 1980 – 2010 the policy emphasis was on the effective and efficient use of land and property assets. In the 10 years that followed a shift towards outcomes, collaboration, shared resources and recognising property as an enabler for environmental change can be observed. The Cabinet Office Property Asset Management Capability Assessment Model (2014) asks the question *'...are there sustainability objectives for the property portfolio that are measured over the medium-to-long term?'* In 2018 the Chartered Institute of Public Finance and Accountancy (CIPFA) acknowledges the importance of Carbon Management and Energy Strategies in developing a strategic property asset management framework.

By 2021 the 3rd edition of the RICS Strategic public sector property asset management guide demonstrates a significant shift towards wider strategic concerns, moving beyond efficiency, with sustainability acting as "…*a catalyst for asset management transformation".* In the same year the HM Treasury published the 'Government Functional Standard GovS 004: Property' emphasising the importance of property decisions giving due regard to adaptation to deal with risks associated with climate change. Similarly, in 2021 the UK Government Property Function also explained through the Net Zero Estate Playbook that "…*decarbonising the public estate will play a pivotal role in our fight against climate change".* In Northern Ireland the Audit Office (2021) published 'A Strategic Approach to the Use of Public Sector Assets – A Good Practice Guide for Local Government in Northern Ireland' highlighting that '…*public sector asset management practices…, have found an increased relevance'* in relation to responding to climate change. In Wales the Welsh Government published a refreshed Corporate Asset Management Strategy 2021-2024 with objectives to *'…manage and maintain property effectively, efficiently and sustainably',* and to manage conflicting priorities to stimulate sustainable development and growth. Meanwhile in Scotland the Scottish Futures Trust (SFT) issued a guide to property asset strategy in August 2022 placing an emphasis on *'…making the most of existing assets'*. The SFT in June 2022 also outlines the need to transition discreet elements of existing operational PPP assets to net zero, but acknowledges that doing so will be challenging and dependent on collaboration.

By the end of 2022, a material shift in the focus of asset management policy can be observed across all four UK jurisdictions, with sustainability now integral to the management of public asset portfolios. Illustrating the policy context is increasingly supportive of the sustainable provision and management of public sector asset inventories. This development is important given that asset management is driven by the development, application, and coordination of public policy instruments that act as an enabler for asset management (Batac et al, 2021). The literature reviewed suggests good intentions in terms of policy development and the ambition for a smaller, greener, sustainable public estate, however there is no evidence of the funding mechanisms required to deliver a new sustainable public estate.

RQ 2. How has the nature of Asset Management professional practice evolved in the UK?

Cagle (2003) explains that *"…managing an asset is no more a ''simple'' technical issue, but a complex problem, on which managers must make operational, tactical, and strategic decisions to meet the client's needs*". The BSI ISO 55000 (2014) describes asset management as "…*the coordinated activity of an organisation to realise value from assets*". The IAM (2015) makes the point that *"…modern society is heavily reliant on physical assets"* and *"…managing assets so they can provide products and services now, and into the future, is a core part of the discipline known as asset management*". RICS (2021) defines Strategic Asset Management as the activity of aligning property assets with the strategic aims and direction of the organisation and adding both financial and non-financial value to the organisation. The SFT (2022) stresses the adoption of a systems-based approach combined with systems engineering and an investment hierarchy that prioritises existing assets (Annex D). Looking back over the last 20 years, it is possible to observe a maturing discipline, and a transition from building and portfolio thinking, to system-based thinking, asset stewardship, and an increased emphasis on existing built assets over new assets. All of which is consistent with the UK Green Buildings Council view that 80% of buildings which will be occupied in 2050 already exist.

RQ 3. What is the relationship between Asset Management and Sustainability?

Policy perspective: as highlighted above, since 2010 the UK public sector has experienced a shift in policy, with sustainability becoming a central objective for the management of the public sector estate. Further recent examples including PAS 2080 (2023) which "…*outlines a carbon management process that is applicable across both infrastructure and buildings, recognising that they have key commonalities and are part of an interconnected system – the built environment*." The NHS Net Zero Building Standard (2023) establishes a set of performance criteria for a net zero carbon building – in both construction and in operation, challenging asset managers to build nothing or only build new as a last resort. Importantly this signals a growing recognition that there is a requirement to limit further (unsustainable) growth of the public sector asset base, but again no indication regarding the processes and mechanisms by which the unsustainable provision of public sector asset inventories will be phased out. The shift in policy towards sustainability as a strategic objective has also been accompanied by an increased focus on the adoption of a system-based perspective (RICS, 2021., SFT, 2022., and PAS, 2023) and an increased emphasis on strategic asset management. So, in terms of policy, it appears that the discipline of asset management is fundamental to delivering a sustainable public sector estate.

Operational perspective: at an operational level the proposed solutions for advancing sustainability are numerous and diverse. Including the likes of utilising BIM for conducting sustainability analysis on existing buildings (Re Cecconi, Maltese, and Dejaco, 2017) waste management, sustainable procurement, retrofitting, embodied carbon management and green certification schemes (Gunatilake and Perera, 2018), Lifecycle Cost Assessments (D'Incognito, Costantino and Migliaccio, 2015) and Whole Life Costing (Scottish Government, 2023). The HM Treasury's Green Book (the basis for UK public sector expenditure business cases) states that when valuing the costs and benefits of project options, such costs and benefits should normally be extended to cover the period of the useful lifetime of the assets being evaluated (i.e. whole-life costing), as well as giving consideration to wellbeing, impacts on air quality, environmental impacts, intergenerational wealth transfers and greenhouse gas emissions. It is apparent the UK public sector has both policy and investment appraisal tools to support a holistic and sustainable approach to providing and managing built assets. However, there is no indication how an investment decision based on whole life costs, which considers the future costs associated with maintaining a built asset, ensures the money is made available to maintain the asset in the future, thereby avoiding unsustainable backlogs and premature obsolescence. This suggests a gap in current practices. It also begs the question, why conduct the whole life cost analysis if the finance and budgeting system has not adjusted to ensure the budget is available in the future to maintain the assets – indicating a potential disconnect between the finance discipline and the asset management discipline.

Strategic perspective: at a strategic level Ruddock and Ruddock (2019) assess the role of investment in built assets in terms of economic growth and how measures based on national income (i.e. gross domestic product (GDP)) are short-term indicators which give little consideration of the long-term capital base of an economy. Consideration of capital wealth provides a different perspective from that of GDP, switching the focus from the flows of monies (income) to stocks of assets (wealth). Such an approach stresses the importance of preserving a portfolio of capital assets which is clearly a sustainable approach. As an economy reaches an advanced stage, the volume of construction activity reduces relatively but not absolutely. Importantly the type of activity changes, and those with established building stocks should find that building activity becomes more orientated towards repair and maintenance. Interestingly, this activity is not typically included as investment (or capital formation) in the national accounts. This alternative whole system perspective, which is focused on asset stocks, is more consistent with recent policy developments and professional guidance (RICS, 2021., SFT, 2022., and PAS, 2023), again suggesting that accounting, budgeting and financial treatments may not be keeping pace with the requirement to pivot towards managing national asset stocks on a long-term basis, which ultimately encourages sustainable outcomes and the preservation of capital value. A further study by Pantzartzis et al (2016) identified capital and revenue availability as critical to achieving long-term interventions for backlog maintenance. In this study four out of the seven respondents stated that capital availability was the main constraint.

It appears that modern built asset management, at both a strategic and operational level, is increasingly orientated towards delivering sustainable outcomes, but constraints on capital funding along with budgeting practices may be impeding progress. Again, suggesting a gap in current research and practice.

RQ 4. The relationship between capital investment planning and built asset management?

Kaganova (2011) explains that there are deep connections between asset management and capital investment planning, which public bodies must factor into the Capital Investment Planning (CIP) process. It is suggested that capital investment should be considered within the frameworks of life cycle costing and assessment of alternatives, with consideration given to reducing demand for the asset and providing the asset by other means. The connection between the availability of monies and asset management decisions is a recurring theme. Batac et al (2021) argues that the major challenges today are related to financial sustainability, due to the limited power of regulators to rehabilitate funding gaps. Bullen (2011) explains that a multitude of financial considerations are used by building owners and operators when confronted with a decision to reuse or demolish their built assets, however, fundamentally the decision to reuse or demolish built assets is driven by economic considerations (i.e. development costs, project costs, investment returns and the market) and a desire for short-term profits. The work of Malekpour et al (2017) explores why strategic planning for infrastructure represents a major challenge and why it frequently returns unsustainable outcomes and that little is known about how investment planning processes are undertaken in practice, and what problems in the procedural aspects lead to deviations from the vision of sustainable development. This work acknowledges that investment in assets continues to have adverse social and environmental impacts resulting in a divergence between vision and practice.

It appears effective capital investment planning is key to asset managers delivering sustainable outcomes, a point that is rarely made in the contemporary asset management literature reviewed. The majority of the literature reviewed focuses on technical solutions or policy perspectives with extremely limited consideration as to how these solutions will be funded and how investment planning processes must deliver sustainable asset inventories (or stocks). The connection between long-term capital investment planning and ensuring the monies are available to service the long-term financial liabilities associated with the public estate, represents an area for further research. We appear to be providing public sector assets without due regard for future generations and future financial liabilities.

DISCUSSION

Opportunities & challenges associated with integrating sustainability principles into UK public sector asset management policy and practice: reflecting on the literature reviewed, it is apparent that the technical solutions exist to decarbonise the built environment (Re Cecconi, Maltese, and Dejaco, 2017., Gunatilake and Perera, 2018., D'Incognito, Costantino and Migliaccio, 2015) and that the policy context is supportive of sustainable asset provision (HM Treasury, 2021., SFT, 2022) as is the guidance for built environment professionals (RICS, 2022., IAM, 2015). Commonly cited challenges referenced by Woodhouse (2003) include the likes of short termism, education gaps and resistance to change. What is also clear is that the shortfall in capital funding and long-range investment planning is less well developed (Pantzartzis et al, 2016). A paradigm shift may now therefore be required, to move away from the current practice of "design, build and forget", to a more sustainable approach (Saeed, M. and Shafqat, A. 2017)

The role of capital investment in delivering a sustainable public estate: the importance of capital investment planning in delivering sustainable asset management outcomes is less well made and less well understood (Kaganova. 2011., and Malekpour et al, 2017). Public sector capital investment has declined in the UK since 2009 (Campbell and Wheatcroft, 2018). Unlike other asset owners, governments are typically reliant on future tax revenues and borrowing to fund financial commitments. While other asset owners use rents, borrowing against cashflows and sinking funds to help service asset liabilities and maintenance backlogs. With UK public debt close to £2 trillion, and no monies set aside for the £1.9 trillion in unfunded public service pensions and nuclear decommissioning, it is likely that investment backlogs will continue to grow as the UK public sector is forced to sweat its asset inventories, due to insufficient capital funding. This raises a series of fundamental questions regarding the sustainability of the current model for public sector asset provision and management. The literature reviewed in this study could be interpreted as the case for change or the case for a new paradigm. The mechanisms adopted in the private sector to prevent an unsustainable dynamic between asset liabilities and the funding to service the asset liabilities typically include sinking funds, reserves, rents, protected budgets and guaranteed levels of investment. The uncapped provision of public sector assets appears to be at odds with modern sustainability theory, and as evidenced above, is at odds with emerging public sector policy and professional guidance. Yet current approaches appear to support the ongoing and unsustainable growth in maintenance and investment backlogs across the public estate.

A new and sustainable paradigm for the provision of the public estate: in adopting a system-based perspective, as advocated by the SFT and RICS, mounting backlogs suggest that the capital funding currently available is insufficient to sustain public sector asset stocks. The links between capital investment planning and sustainable asset management outcomes does not appear to give sufficient consideration to the long-term asset liabilities that exist across the public sector (Stewart and Connolly, 2022), despite the increased focus on whole life costs. Perhaps therefore it is time to align asset provision with budget availability, and put in place new control mechanisms to achieve a sustainable dynamic. KPMG Economics (2017) demonstrated that public sector capital stock is *'…consumed at a rate of about 2.5% p.a.'* and that, ignoring inflation, 2.5% p.a. is required to maintain and operate public sector asset inventories. However, capital spend just equivalent to depreciation does not maintain the 'status quo'. New and emerging demand for infrastructure, fuelled by factors such as population growth, innovation, environmental degradation and economic growth, create a capital formation gap. In conclusion, KPMG recommends that public sector capital investment should average between 5.5% and 6.0% p.a. of capital value. In combination these basic facts could underpin a new conceptual construct for the sustainable provision and management of public sector asset inventories. This hypothetical construct is depicted in Figure 1 below, in a model which seeks to align asset provision to long-term budget availability, in a balanced and sustainable dynamic, based on circa 5% of capital value being reinvested annually. Thereby delivering a balanced system, which is in stark contrast to the short-term perspective that currently prevails in local and central government due to short-term budgeting cycles.

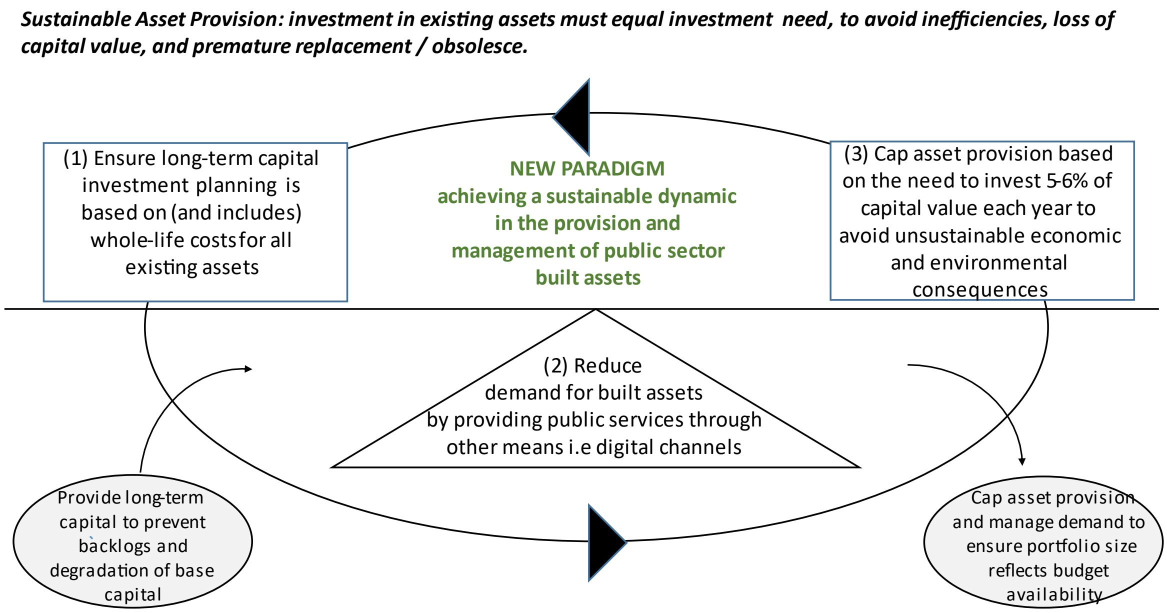

Figure 1 A new hypothetical construct for delivering a sustainable public estate based on balancing asset provision with long-term budget availability. Source: Authors construct.

Such an approach allows for the quantum of assets provided to be curtailed by the amount of capital available to service their long-term investment requirements. Under such an approach, built assets would routinely receive 5%+ capital investment preventing investment backlogs, portfolios would be resized based on what could be afforded, and any unaddressed need for public services would be met through other means, such as digital services.

Such an approach may seem extreme to some, however, we appear to be at a critical juncture in terms of the climate crisis. As recently as June 2023 the World Bank stated that "climate change has amplified the call for a new perspective on public asset management".

CONCLUSION

This paper has examined a broad range of contemporary asset management literature, UK public sector policy and professional guidance. It can be concluded that sustainability is integrated into asset management policy across the UK. The process of capital investment planning in delivering a sustainable public estate is not however clear, nor is the relationship and impact of capital investment planning upon asset management in the UK. In addition, it is not clear what actions the UK government is taking to align long-term asset liabilities with the long-term availability of funds to maintain the UK public estate. Providing and maintaining built assets without the long-term capital funding to maintain them is inconsistent with sustainability theory, public sector policy, and professional guidance. This observation underpins the case for a new paradigm for the provision and management of public sector assets, based on living within financial and environmental limits, and not providing more assets than can be afforded.

Based on the literature reviewed, a new paradigm for sustainable asset provision and management could potentially, as illustrated in Figure 1 above, incorporate features such as:

1. Ensure long-term capital investment planning and asset management are more closely integrated, with long-range budgets set to reflect the long-term investment needs of existing assets, thereby slowing the degradation of base capital.
2. Actively minimise reliance on built assets to deliver public services, thereby reducing the quantum of long-term liabilities and the risks associated with asset failure, helping to balance investment need and the level of funding available.
3. Limit asset provision based on long-term affordability (budget availability) to encourage a more sustainable dynamic thereby preventing the practice of building assets and then failing to maintain them, which is environmentally, economically, and socially unsustainable.
4. Adopt mechanisms such as sinking funds, rents, 100% cost recovery, limits on portfolio size, or protected reserves to ensure backlogs do not arise through lack of long-term funding (perhaps even crafting a new variant of the traditional PFI / PPP model).

Finally, further research to understand if similar dynamics and asset management challenges can be observed beyond the UK would be beneficial. Such research could determine the extent of the requirement for a new paradigm, and whether alternative models exist outside the UK that avoid the investment backlogs which currently exist across the UK public sector estate.

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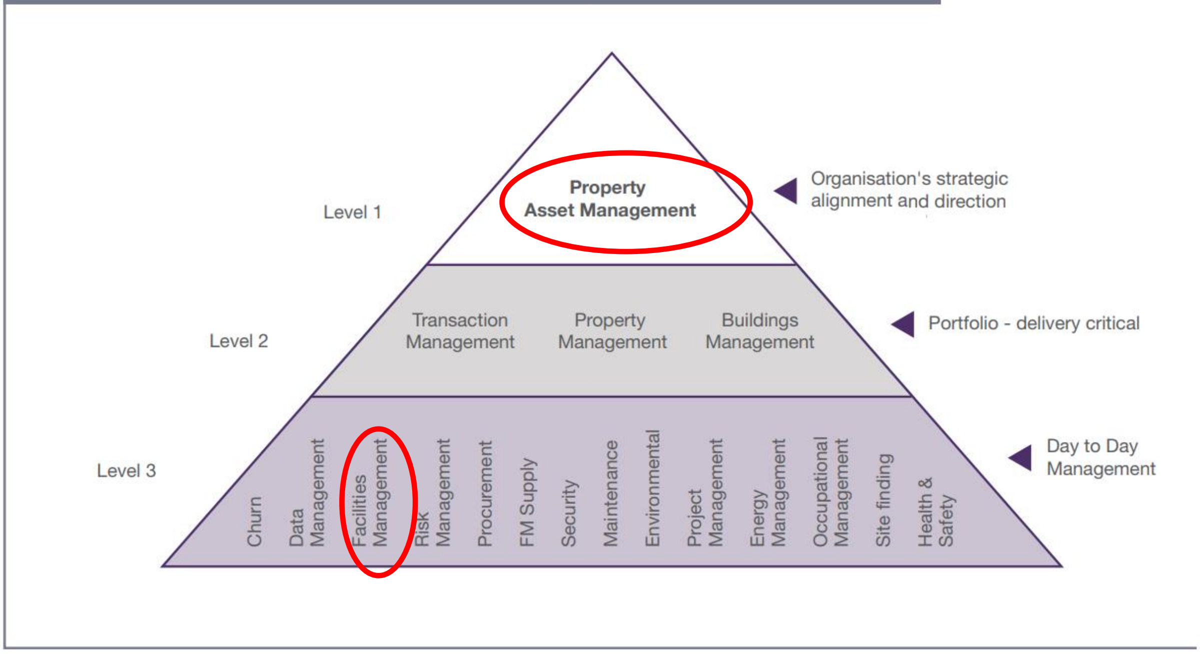
Appendix A Relationship between Property Asset Management and Facilities Management. Royal Institution of Chartered Surveyors (RICS), Public Sector Asset Management Guidelines, 2nd Edition (2012).

Figure 1.1: Property asset management and property management interrelationship



Appendix B Detailed Research Methodology.

A Systematic Literature Review (SLR) was conducted with the aim of answering an overarching research question…, what can literature tell us about why managers of the built environment continue to pursue investment and expenditure activities that only partially address sustainability policy objectives?

This in turn supported the consideration of four research questions:

- RQ 1. What is the UK Policy context for public sector asset management?
- RQ 2. How has the nature of Asset Management professional practice evolved in the UK?
- RQ 3. What is the relationship between Asset Management and Sustainability?
- RQ 4. What is the relationship between capital investment planning and built asset management?

The adopted methodology is subject to various limitations. Firstly, a literature review can be superficial in nature lacking depth, and systematic review techniques can be prone to subjectivity. However, the approach adopted was designed to minimise bias and increase methodological accuracy and rigour. Automatic and manual approaches were adopted for sampling and analysis, to optimise the validity and credibility of the results. In addition, multiple sources from only quality peer reviewed journals were used to ensure representativeness.

Question Formulation (Step 1)

The research questions were formulated based on the combined academic and professional domain knowledge and experience of the two authors, thereby ensuring the domain was suited to the proposed questions. They were then iteratively adjusted over the life of the literature review.

Select Methodology (Step 2)

A hybrid research methodology was adopted based upon digital library searches and snowballing technique (Mourão, E. 2020), combined with an abridged iterative Systematic Review (iSR) approach (Lavallée, Robillard and Mirsalari, 2014), structured on the following steps:

Step 1. Question formulation: define the research questions.
Step 2. Select Methodology: hybrid, iterative, systematic etc.
Step 3. Search Strategy: define scope and search strings.
Step 4. Selection Process: Inclusion and exclusion criteria.
Step 5. Strength of evidence: what makes a paper high value/quality.
Step 6. Analysis: extract evidence from selected papers.
Step 7. Synthesis: Structure evidence and draw conclusions.

Search Strategy (Step 3)

A decision was taken to use the Anglia Ruskin University electronic online library search portal (https://library.aru.ac.uk/) which provides access to hundreds of Journals and Databases covering the built environment, economics, policy, earth sciences, law etc. Similarly, a decision was taken to focus exclusively on peer reviewed papers associated with built asset management.

A backward snowballing technique was adopted (Gray, 2022) to identify cited publications from peer reviewed journals and articles available through the Anglia Ruskin University electronic online library search portal, which allows online collections, journals, journal articles and databases to be accessed with a single search.

Separately an unstructured review of grey literature was conducted drawing from professional body and UK public body websites. Grey literature was deemed appropriate as the lead author is working towards a Professional Doctorate, and research associated with a Professional Doctorate, be it research of an applied or basic nature, should create knowledge which relates to everyday practice (Jamieson, I. and Naidoo, R. 2007 and Fenge, L. 2009), meaning grey literature was deemed to be of value as it provided a bridge between academic research, policy and professional practice.

Selection Process (Step 4)

Conditions for the initial selection of papers was based on research relevance and included title, subject, abstract and key words. Several search strings based upon a 'population AND activity AND outcome' structure included:

String 1. Public Sector + Asset Management + Policy
String 2. Built Asset Management + Investment + Sustainability
String 3. Built Asset Management + Standards + Sustainability
String 4. Built Asset Management + Theory + Sustainability
String 5. Built Asset Management + Mitigation + Sustainability
String 6. Built Asset Management + Adaptation + Sustainability
String 7. Asset Management + Capital Investment Planning + Sustainability
String 8. Public Sector + Capital Investment Planning + Sustainability

These searches were applied to the period 2000 to 2023, with the 'population' targeted at the publication title, with the other terms / phrases in each string targeted at title, subject and content.

This delivered an initial set of 783 papers that were sifted to result in 25 selected papers. The next search used backward snowballing based on examining the reference lists to deliver a further 8 papers.

Table 1 Summary of Selection Process. Source: Authors origination.

String	Initial search result	Number of Papers Selected	Backward Snowballing Result
String 1	22	3	2
String 2	101	8	5
String 3	139	4	0

String 4	88	2	1
String 5	23	1	0
String 6	40	4	0
String 7	42	0	0
String 8	328	3	0
TOTAL	783	25	8

Strength of evidence (Step 5)

Conditions for including and excluding papers was centred on research quality, which was determined, having read the paper in full, by taking an overarching view based on whether it was clearly written, presented a robust argument, or underpinning rationale, and included robust conclusions. Inclusion required a paper to be (1) clearly written, (2) present a robust argument, and (3) included robust conclusions.

Analysis and Synthesis (Step 6 and Step 7)

Each paper was examined to extract the relevant information and data, based on Janzen and Ryoo's four step process. Step 1, each selected paper is summarized in a single paragraph. Step 2, each summary paragraph is further summarized into a single phrase. Step 3, The summary phrases from all the selected papers are put together to see how they support or contradict one another. Step 4, A single paragraph is built based on the phrases summarising all the selected papers.

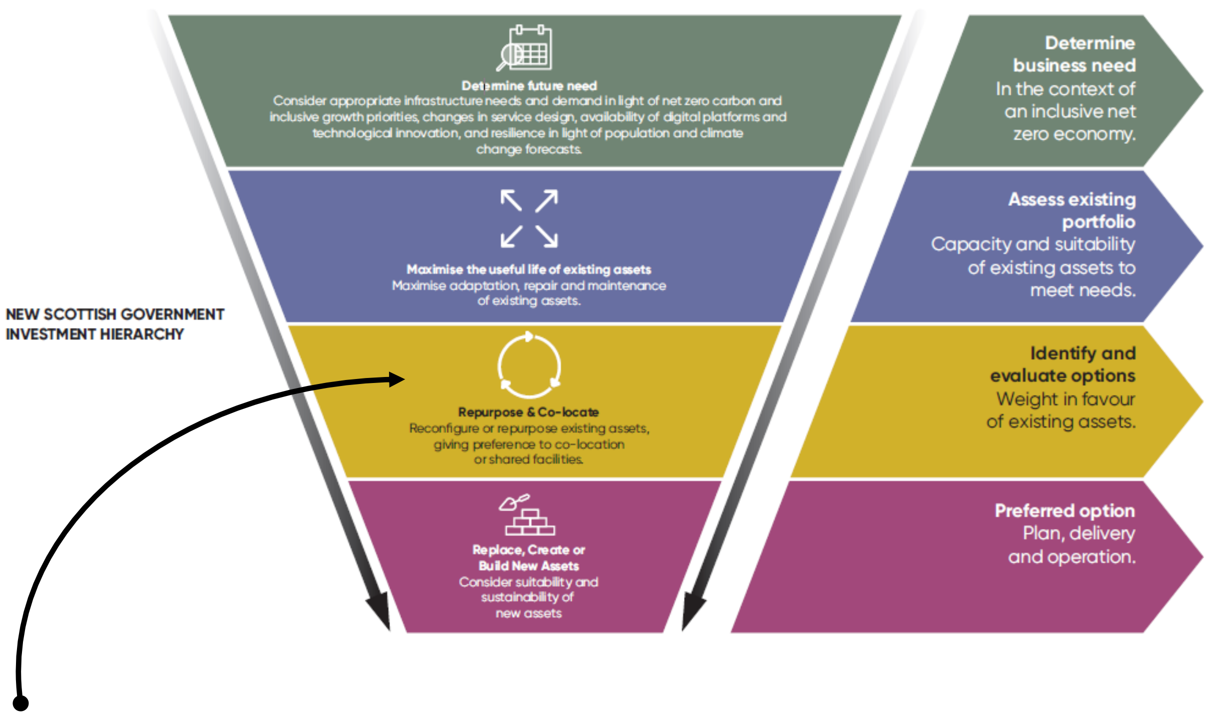
Appendix C Full list of Journals and Databases accessed via the Anglia Ruskin University electronic online library search portal.

Anglia Ruskin University electronic online library search portal pulls results from almost all the databases and journals the university subscribes to.
A full list of all the databases Anglia Ruskin University has access to can be found at:
https://anglia.primo.exlibrisgroup.com/discovery/dbsearch?vid=44APU_INST:ANG_VU1
and the full list of journals available can be found at:
https://anglia.primo.exlibrisgroup.com/discovery/jsearch?vid=44APU_INST:ANG_VU1

The specific Journals and Databases accessed in undertaking the review detailed in Annex B are as follows:

Specific Databases Accessed	Specific Journals Accessed
Academic OneFile. AJ Buildings Library. Art Design and Architecture Collection ASTM Standards BCIS. British Standards Online. Business Source Premier. CIS : Construction Information Service Digimap. Ordnance Survey. Emerald Management. Emerald Premier: Engineering. ICE Virtual Library. ISURV. JSTOR. Lexis+ UK ProQuest SciTech Premium Collection. ScienceDirect. Scopus. Web of Science. WestLaw UK.	*Building Research & Information* *Built Environment Project and Asset Management* *Canadian Journal of Civil Engineering* *Engineering, construction, and architectural management* *Environment and Planning* *FM in the experience economy* *Journal of Infrastructure Development* *Journal of the Soil-Structure Interaction Group in Egypt* *Information and software technology* Public Money & Management *Social Work Education* *Sustainability* *Water*

Appendix D Scottish Government Asset Investment Hierarchy. Source: Scottish Futures Trust (SFT) (2022).



The hierarchy for investment illustrated above demonstrates a clear preference for repurposing existing assets, when addressing business need for built assets, over and above creating or building new assets.

European Facility Management Network (EuroFM) is the platform organization that brings educators, researchers and practitioners in the field of Facility Management together. The aim is to bring forward the FM profession and to come to a better mutual understanding by learning and sharing FM knowledge.