

MIND THE CHASM: INTEGRATING FACILITY MANAGEMENT REQUIREMENTS IN DESIGN

Oldouz Arshang¹, Moslem Sheikhhoshkar², & Farook Hamzeh³

ABSTRACT

Operation and maintenance (O&M) costs include approximately 80% of a facility's overall expenses, while facility managers are often excluded from decisions made during the design phase. This disconnect results in a mismatch between the actual performance of the facility and what the design outcome is intended to be, leading to higher O&M costs and transfer of inadequate information during handover. While Lean Principles and digital platforms are proposed as solutions, practitioners lack a shared understanding of FM problems to meaningfully integrate FM requirements during design. This study addresses the gap through the lens of Transformation-Flow-Value (TFV) theory, and uses a DSR methodology combining problem identification from literature, extraction, and consolidation of FM requirements. The extraction produced 55 factors, which were grouped into 22 categories spanning stakeholder involvement timing, information quality, maintainability, and sustainability. The proposed taxonomy is lean-consistent and uses TFV theory also as a rule to classify ambiguous factors. This research methodologically contributes to the body of knowledge by developing a practical and structured taxonomy of FM requirements that supports early FM involvement and strengthens designers' ability to address FM needs in design reviews across different project delivery settings.

KEYWORDS

Facility management, design, integration, lean construction, taxonomy.

INTRODUCTION

Buildings spend most of their life in operation, the period that has been reported as the dominant share of lifecycle cost. While this phase is accountable for approximately 80% of the expenses (Thompson & Nassereddine, 2021), its operational efficiency is influenced by decisions made during design (Dahl et al., 2005). According to “National Chart of Life-Cycle Facility Costs”, small attention and investment within the early stages of a facility development through integrated approaches can prevent high O&M costs (Carbonari et al., 2015). On the other hand, once a building passes the design phase to execution and handover, the chance to meaningfully improve outcomes decreases considerably (Christian & Newton, 2002). Meanwhile, Abou-Ibrahim & Hamzeh (2022) emphasize that poorly managed design processes can decrease the efficiency of the workflow and the satisfaction of users of the facility. Mayouf et al. (2014) also link operational challenges to failures regarding building's functional assessments when designing the facility. Therefore, standards and guidelines such as BS 8536_1 consider the

¹ MSc Student, Civil and Environmental Engineering Dept, Hole School of Construction Engineering, University of Alberta, Edmonton, Canada, arshand@ualberta.ca, orcid.org/0009-0008-9770-1247

² Visiting Scholar, University of Greenwich, School of Engineering, London, UK, m.sheikhhoshkar@greenwich.ac.uk, orcid.org/0000-0001-9067-2705

³ Professor, Civil and Environmental Engineering Dept, Hole School of Construction Engineering, University of Alberta, Edmonton, Canada, hamzeh@ualberta.ca, orcid.org/0000-0002-3986-9534

eventual performance of buildings as one of the prominent parameters in early stages for a smooth linkage between design and the final output (The British Standards Institution, 2015).

As stated by Jensen (2009), the Facility Managers' (FM) role in an organization is to manage and run the facility. Since facility managers work with day-to-day building performance and deal with occupants of the facility, they possess crucial information regarding building needs, and this knowledge is necessary during the early stages (Jensen, 2009). Therefore, facility managers can clarify how functional requirements dictate system selection and help align maintainability goals with the technical needs of the occupancy.

However, despite the recognition of FM as a discipline since the 1970s (Bascoul et al., 2018), many buildings are still built without having FM systematically involved during design (Bascoul et al., 2018; Jensen, 2009). Studies consistently highlight that early engagement of FM is important for practical design outcomes and operational problems prevention, and ultimately, to ensure buildings meet their intended performance (Attobrah et al., 2021). Prior studies investigated and reported recurring barriers to this integration, such as limited FM input during design development and review stages, along with unclear and insufficient communication between designers and FM within the design process (Fatayer et al., 2019). Even when integrating, current practice involves FM specialists and gets their input too late (Attobrah et al., 2021), which triggers costly design modifications (Bascoul et al., 2018). Other works done by Way & Bordass (2005) and Murguia et al. (2020) recommended injecting lessons learned from previous projects into upstream stages within design to strengthen early-stage decisions (Way & Bordass, 2005), but still, this important goal is rarely achieved in practice (Murguia et al., 2020). Although the literature in overall supports the importance and benefits of FM contribution, it also indicates the challenge regarding the translation of FM experience into design considerations.

These studies point to an implementation gap: the lack of a structured definition of FM requirements for designers to make the FM contribution effective. While the previous studies acknowledge that FM input is required at early design, Jensen (2009) studied the process of communicating input between FM and designers. They stated that FM knowledge is not systematically structured as design criteria and translated into design (Jensen, 2009). Therefore, even when teams are willing to integrate FM knowledge, there may be a lack of common vocabulary that makes FM expectations visible and manageable in design settings.

Addressing this gap requires recognition of FM importance as well as providing a structured way to identify and organize FM needs to use during design. This study develops a preliminary taxonomy of long-term FM requirements that consolidates the factors important for FM to effectively operate and maintain a building, recurring pain points and inefficiencies from the lens of FM found in the literature and confirmed by industry experts. It applies Design Science Research (DSR) methodology to answer a fundamental question: what are FM requirements that should be considered during the early stages?

As a response to the research question, this study fulfills the research objectives as follows:

- Synthesis of FM-related factors from prior research that link design decisions and information practices to O&M outcomes.
- Consolidate these factors into a smaller set of FM requirement families that are conceptually coherent and usable in design reviews.
- Present the resulting taxonomy as a structured vocabulary to support early FM engagement and reduce downstream operational inefficiencies.

This taxonomy is based on both academic sources and expert experience, making it a structured and lean-consistent vocabulary useful for future FM knowledge integrations.

LITERATURE REVIEW

THE FM-DESIGN INTEGRATION CHALLENGE

This chasm or gap between Facility Management and Design is a widely recognized challenge in the built environment, and is linked to the broader disconnect and lack of coordination among various disciplines involved throughout a project's lifecycle (Dahl et al., 2005). This isolated practice leads to a mismatch between the anticipated and actual performance of a facility (Bascoul et al., 2018; Fatayer et al., 2019). Beyond performance consequences, this gap results in the transfer of inaccurate and insufficient information during and after handover (Gordo-Gregorio et al., 2025; Tsay et al., 2023). This highlights not only the awareness of FM value, but also how FM needs are captured and maintained throughout the building project.

EARLY FM INVOLVEMENT AND KNOWLEDGE INTEGRATION

Design decisions dictate downstream operational performance. Due to the nature of design, it is an interdisciplinary practice, and its outcomes depend on the quality of coordination among different parties (Abou-Ibrahim & Hamzeh, 2022). While engaging FM in the early stages improves the efficiency of the building, the lack of involvement results in several issues during occupancy (Meng, 2013). From this perspective, early FM involvement is not only about including FM as another stakeholder, but also is about ensuring that design decisions are aligned with the desired maintenance outcomes when design is still flexible. Effective knowledge integration also relies on the definition of the stakeholders and their responsibilities, and it is to be specified by the owner (Ghannoum et al., 2019).

INFORMATION QUALITY FOR FM INTEGRATION

A central aspect of the FM-Design gap is the quality of information and the structure of what FM teams receive at handover. Building Information Modelling (BIM) has been presented as an enabler to ease this integration and act as an acceptable platform to maintain and transfer required building information for FM teams (Tsay et al., 2023). Recent work has demonstrated potential benefits of combining BIM with integrated delivery approaches. For instance, Bazan Montalto et al. (2024) have combined BIM with Lean and Virtual Design Construction in their study for FM, and have witnessed a significant reduction in terms of the time spent on maintenance (Bazan Montalto et al., 2024).

However, despite these benefits, BIM alone does not guarantee effective FM integration. Studies consistently show that data inconsistencies are a major challenge to benefit from the full potential of digital delivery (Tsay et al., 2023). In other words, useful FM outcomes depend on clearly defined information requirements and a coordinated process for producing required asset information (Tsay et al., 2023). Other study also reveals that BIM could be only partially practical for FM teams if there are shortcomings in terms of sufficient and managed data to feed into BIM models (Mayouf et al., 2014). Tsay et al. (2023) analyzed BIM information quality in comparison with owners' information requirements. They found a considerable gap in terms of content and structure, which causes a barrier for FM use (Tsay et al., 2023). Another study divided FM practice into areas such as "maintenance", "space management", and "energy" (Gordo-Gregorio et al., 2025). They investigated challenges in applying BIM to these areas and found out that there are persistent information issues across FM functions (Gordo-Gregorio et al., 2025). Collectively, it implies that without a clear definition of FM priorities and information needs, digital tools may not tackle silos, and design teams might produce models that are extensive in terms of geometry but have limited operationally relevant data.

LEAN CONSTRUCTION AND TFM THEORY

Lean Construction, on the other hand, offers an additional perspective by proposing structural solutions for higher quality of operational performance of an organization, and focuses on value generation and elimination of non-value-adding activities (Bazan Montalto et al., 2024). Sheikhhoshkar et al. (2023) have examined and proved its effectiveness in terms of BIM-lean integration for information management in planning and control practices. Central to this approach is the Transformation-Flow-Value (TFV) theory, developed by Koskela et al. (2007). It standardizes production by reintroducing it as these views: transformation of inputs to outputs, flow of information and work, and value defined by customers (Koskela et al., 2007). The application of TFM in studies includes the study done by Abou-Ibrahim & Hamzeh (2016) in the context of design and BIM. Their study proposes a TFM-based perspective to manage the design, and explores how design decisions with required Level of Development (LOD) can be aligned with flow and value requirements (Abou-Ibrahim & Hamzeh, 2016).

When looking through the TFM theory of lean, the problem of FM integration and the gap between FM and design is due to weak flow, unclear transformation, and misunderstood value. For instance, the problem of FM teams receiving inaccurate data can be understood through TFM: Transformation relates to the exchange of data and transforming data into design deliverables. Flow is concerned about the movement of reliable information at the right time between stakeholders engaged in that process until they get to the end user, and Value is about defining the set of final documents the client and end users (FM) expect the process to deliver. Therefore, defining the value, transforming the right inputs to outputs, and maintaining the flow of outputs is the key to resolving the issue.

Although prior FM, BIM, and lean-based studies have highlighted the importance of early FM involvement for better lifecycle outcomes and information quality, they do not yet provide a structure that translates these concerns into a set of FM-related operational requirements to consider during early stages. These requirements are scattered across studies and are defined with different terminologies. Therefore, there is a need for a new taxonomy, and TFM provides a suitable conceptual basis for that, because it offers a consistent logic for organizing the dispersed DM factors.

METHODOLOGY

This study is based on a Design Science Research (DSR) approach to develop a practical research artefact that supports early integration of FM requirements in the design. The DSR process is organized into three consecutive phases: problem identification, artifact development, and evaluation through validation and testing, as shown in Figure 1. This paper reports phases 1 and 2, including informal expert feedback. A broader, post-development validation and testing in multiple design review settings happen in phase 3 and are planned as subsequent work.

PHASE 1: PROBLEM IDENTIFICATION

Due to the nature of this phase as an exploratory problem identification rather than a quantitative synthesis, a problem-driven narrative literature review was conducted to frame the core research problem. It enables the integration of conceptual and practice-oriented studies that address FM-design integration and is followed by discussion meetings with FM experts to confirm its relevance in practice. The literature review targeted publications that discuss the misalignment between design decisions and FM/operational needs with particular attention to operational performance, user experience, and information quality during the O&M phase. The initial search started by keywords including “Facility Management”, “Design”, and “Information Integration”. The sources were collected iteratively via snowball sampling, beginning from identified standards and foundational FM-design papers of Jensen (2009),

Bascoul et al. (2018), and Enoma (2005), and this phase followed backward and forward references to gather additional relevant work. In total, 45 sources were reviewed during the snowballing process until observation of thematic recurrence of the same solutions proposed through digital platforms such as BIM and other information compatibility approaches.

In parallel, exploratory discussions with three Canadian practitioners (each with over 20 years of professional experience) were conducted to ensure the problem identified in the literature (FM values not systematically captured in design) also occurs in real projects. The experts represented different roles within the FM domain, including a Director of Facilities and Operations, a Facility Planning Consultant, and a Facility Manager. The expert input was collected through non-structured discussion sessions and served as a formative relevance check to confirm that the challenges identified through the literature reflect a real-world issue. The outcome of Phase 1 was a clearly defined problem that states FM needs are widely acknowledged, but are not yet structured into design-reviewable requirements.

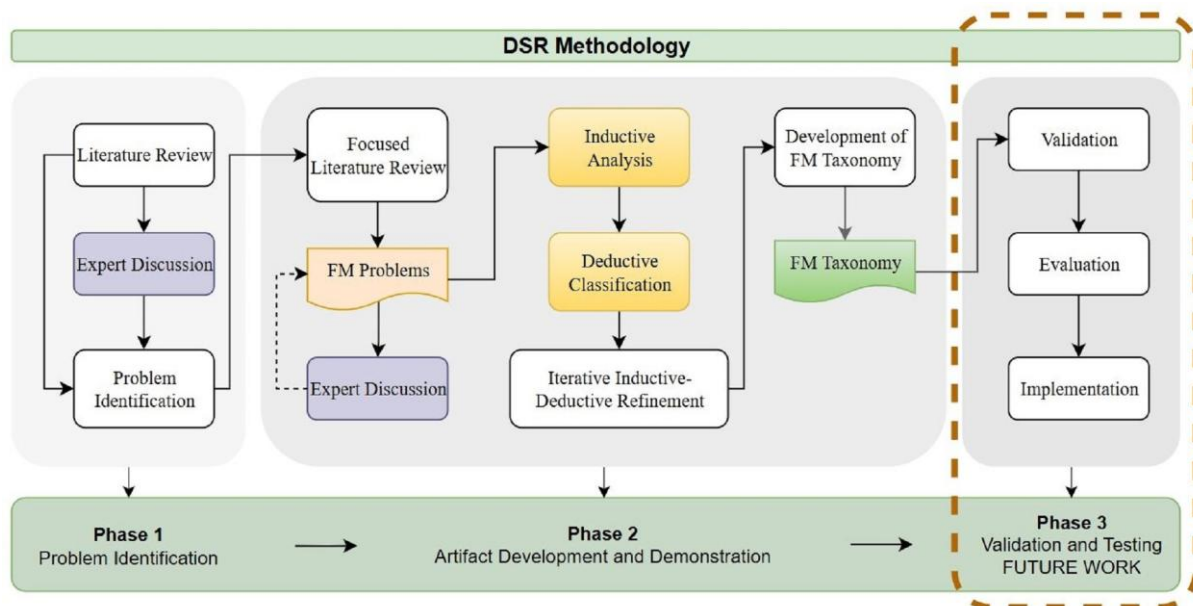


Figure 1: Research methodology

PHASE 2: ARTIFACT DEVELOPMENT

Phase 2 concentrated on developing an artefact, which is the FM taxonomy of problem categories. To achieve the desired outcome, one step was the extraction of specific FM problems and value-related factors that would form the raw materials for the taxonomy, along with rule-based consolidation as the next step.

A focused literature review was carried out from the included sources to identify factors that are rooted in design choices, significantly affect the O&M phase, and are repeatedly highlighted by FM-oriented studies as sources of operational difficulty or complaints from users' perspectives. Factors were included when they were linked to design decisions, knowledge integration and information requirements, had an implication for downstream facility operations or user experience, or were recurring operational issues mentioned in the literature. This step follows a common approach for taxonomy development, also used by Siddiqui et al. (2022), that identifies items through a systematic literature review and then consolidates them into higher-level categories. The result of this process was a list of 55 discrete FM factors capturing values, requirements, and problem areas across several themes.

These 55 factors were then subjected to expert review: the same FM professionals were asked whether the list reflected their key values and recurring operational problems. This step

was informal and is inspired by approaches such as the face-validity exercises detailed by Velikova et al. (2018) where expert review is used to confirm content coverage and practical relevance before formal classification (Velikova et al., 2018).

For the consolidation of FM factors, the study combined the comprehensive list into a structured taxonomy of FM requirements families through a hybrid synthesis process. Identified clusters are thematic, and inductive open coding was applied through comparison of factor descriptions and O&M outcomes. A deductive approach was then applied using a set of rules to ensure usefulness and avoid redundancy. The five consolidation rules to guide the process:

- **R1_Synonyms:** Factors referring to the same idea with different wording (terminology overlap) were merged into one factor.
- **R2_Scope coverage:** Factors with their meaning being fully covered by a higher-level factor were absorbed into broader concepts.
- **R3_Similar O&M outcome:** Factors were grouped when they ultimately result in the same operational outcomes.
- **R4_Primary ownership:** Each factor was assigned to one main family to avoid duplication.
- **R5_TFV tie-breaker:** During the classification process, when family assignment is unclear and a factor fits more than one family after applying R1-R4 rules, the factor is assigned to the family that most strongly improves a TFV dimension during O&M: Transformation (technical), Flow (information/workflow), or Value (end user/performance).

A traceability matrix was maintained to preserve transparency from each original factor to its final family and to check manual coverage across factors. The output of this phase was a structured conceptual vocabulary of 22 FM priorities ready for further validation consideration within design reviews.

PHASE 3: EVALUATION (PLANNED VALIDATION AND TESTING)

In terms of validation, expert discussion sessions were conducted prior to applying inductive-deductive steps and development of the final artifact (within the problem identification phase, and in phase 2, before using consolidation rules to develop the artifact). Therefore, post-consolidation validation and implementation of the artifact are not reported in this paper.

Phase 3 will evaluate the taxonomy through broader validation and testing in diverse design review settings. This phase is outside the scope of the present paper and is planned for future publications.

RESULTS

Results are presented in two sub-sections: factor distribution and taxonomy development.

DISTRIBUTION OF FM FACTORS ACROSS THE LITERATURE

The focused review produced a set of 55 FM factors extracted from academic sources, which collectively describe how design decisions and information structures affect facility operation, maintenance, and user experience. Figure 2 visualises these factors together with the studies that mention them, highlighting where the literature concentrates on topics such as early FM involvement, FM data quality, maintainability, energy performance, and end-user outcomes.

Based on the figure, factors that appear most frequently are related to FM involvement, lifecycle performance (reduced cost, energy efficiency), end user perspective (occupant comfort/needs, post occupancy evaluation), information- related factors (data integration, data

interoperability/accessibility, structured information flow), maintainability (ease of maintenance), and space management.

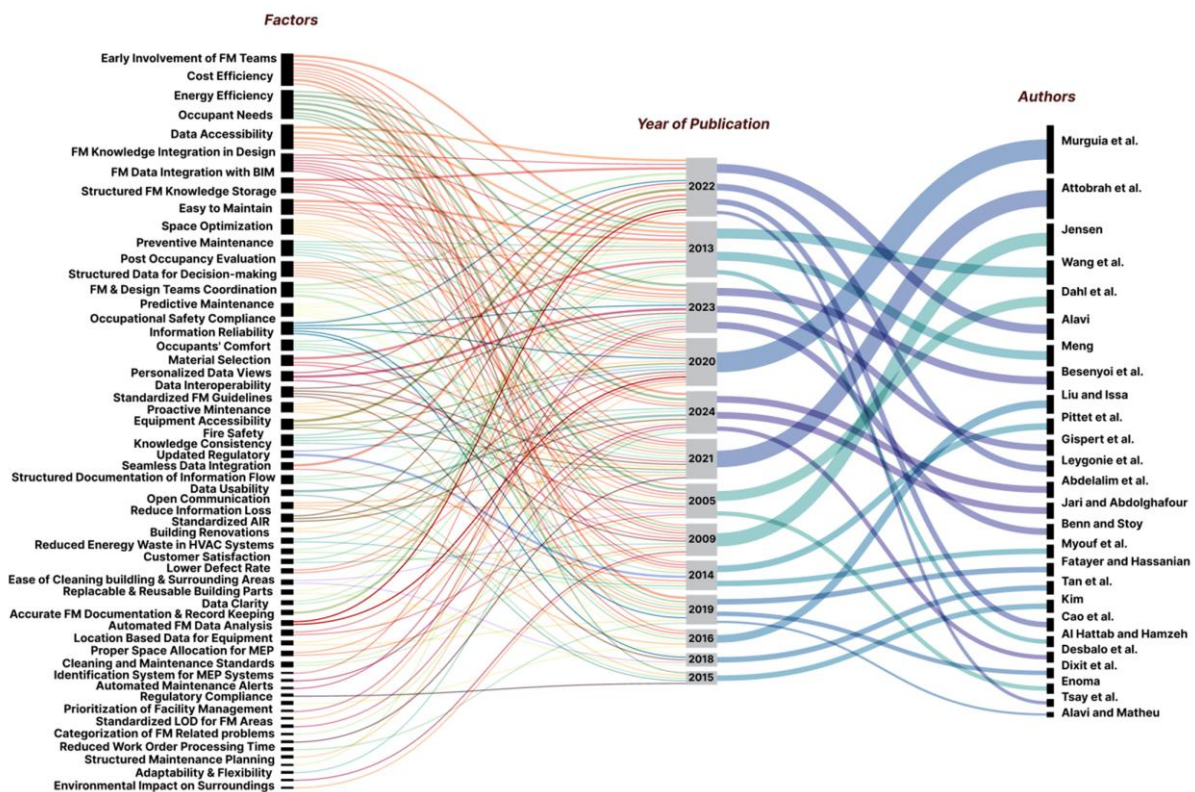


Figure 2: Distribution of FM factors across the literature

CONSOLIDATION OF FM FACTOR FAMILIES AND TFV STRUCTURE

Building on the factor set, the consolidation process produced a flat taxonomy of 22 FM requirement categories by organizing originally dispersed 55 factors, as illustrated in Figure 3. The classification efforts started with the application of consolidation rules and continued until no further merging was possible. These families cover key themes including FM involvement, lifecycle performance, information quality, and maintainability. Rules R1-R4 ensured clarity and avoided duplication by merging overlaps in terms of terminology, concepts and outcomes while enforcing primary ownership.

Rule R5 (TFV tie-breaker) handled the borderline cases that could fit more than one category. As a result of the methods applied in the methodology section, each factor is assigned a unique primary category according to the consolidation rules and TFV tie-breaker criterion. The taxonomy shows how factors such as structured FM knowledge storage, data usability, and data interoperability are grouped into structured FM data for decisions, or how early involvement of FM teams and prioritization of FM are grouped into FM teams involved early. For factors with confusion to clearly assign a primary home to, the TFV tie-breaker was used. For instance, data accessibility at first glance fits both role-specific FM data and structured FM data for decisions. Considering TFV theory in practice, role-specific data availability is primarily about Flow as it ensures timely and reliable information for FM decision-making. Therefore, this factor is grouped primarily into the role-specific data category.

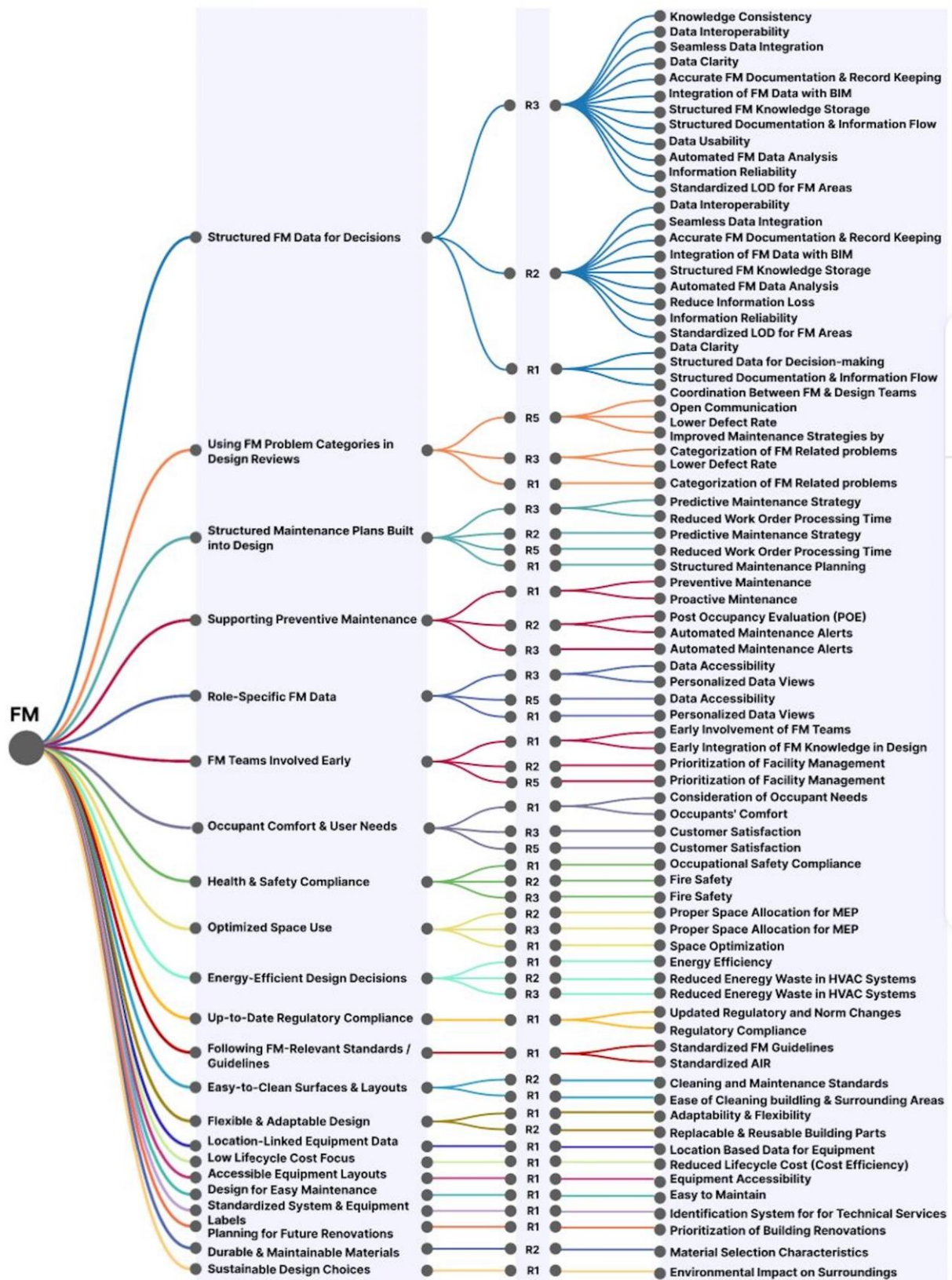


Figure 3: FM requirement categories

The expert feedback also influenced consolidation results. For some themes, such as accessible equipment layouts and easy-to-clean surfaces and layouts, the consolidation rules (R2 and R3) would have allowed merging them into a broader family such as design for easy maintenance. As a result of expert discussions, feedback suggested that these topics need more detailed

attention during design and if faded into a larger category, they might be at the risk of overlook. Therefore, they were kept as separate families despite their relevance to another broader category. This reflects the balance between conceptual consolidation and practical visibility.

DISCUSSION

The concentration of identified factors on the recurring themes indicates that failures in these areas are widely recognised as roots of operational waste and performance gaps, and are not limited to technical defects only; they often stem from fundamental weaknesses in how information and operational needs are defined, transferred, and kept usable through design and handover. From a lean interpretation lens, this distribution aligns with Lean's TFCV theory. It explains that operational waste and performance gaps occur when information flow is unreliable or poorly structured, transformations fail to produce outputs aligned with operational needs, and the value is either not explicitly defined by the customer and users or is not delivered. This acts as a motivation to consolidate factors into a lean-aligned structure for design decisions.

This taxonomy aligns with previous FM-integration literature on early FM involvement (Jensen, 2009), information quality (Tsay et al., 2023), and lifecycle performance (Dahl et al., 2005). Instead of addressing these dispersed issues in isolation, this study consolidates them into a unified structure of 22 FM requirement categories.

IMPLICATIONS

This study both academic and practical implications. From an academic standpoint, the proposed taxonomy consolidates scattered FM requirements from previous studies into a usable set of categories and enables comparison across studies. It also links FM operational challenges to TFCV lean interpretations. Regarding the practical implications, the taxonomy can be used for better organization of design reviews and definition of clearer responsibility assignments for FM-related decisions within design. In addition, ongoing research is extending this work by validating the taxonomy, defining the appropriate timing for FM involvement, and information quality expectations. Therefore, these factors can be embedded as checkpoints within real design processes.

CONCLUSION

This paper focuses on the design-FM disconnect and considers it an early design content and flow problem. While using the TFCV theory of lean principles, it explains how the gap between FM values and design outputs results in inefficient transformation of inputs and emphasizes the importance of flowing the right values across the lifecycle for an effective handover. This study addresses the identified problem through a DSR methodology, encompassing three sequential phases to formulate the problem, identify recurring FM problems and requirements, and develop a concise and structured conceptual FM vocabulary. The development process is based on a long list of FM requirements identified through a problem-driven literature review, and applies consolidation rules with a TFCV tiebreaker in cases with ambiguity. This resulted in a taxonomy of 22 FM factors for consideration in design reviews. It supports reduced rework and improved lifecycle efficiency through stronger collaboration between FM and designers to align design review decisions with required factors and providing the right information.

Although this study involved several informal discussion sessions with experts to validate the output of each phase, the proposed taxonomy is not formally validated for consideration during the early stages by experts through standard protocols. Therefore, future work includes evaluation approaches for further validation of the proposed taxonomy and exploring the gap of implementing the list in different project delivery settings between designers and FM perspectives, which will be published in future publications. This approach will cover phase 3

(validation and testing) as it requires more in-depth validation and is beyond the scope of this study. Moreover, the study covers relevant papers through a narrative literature review to identify valuable factors for FM practitioners. However, a more structured literature review approach, such as a systematic or scoping review, could broaden and strengthen the findings of this study.

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