From Gut Feeling to Data-Driven Decisions

Exploring Digital Twin Supported Decision-Making for Real Estate Management

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Abstract. The real estate sector plays a crucial role in achieving the EU's Green Deal climate goals. As 85–95% of today's buildings are expected to remain in use beyond 2050, sustainable management and renovation of existing building stock have become key strategic priorities. Despite increasing sustainability requirements, decision-making in Real Estate Management (REM) still relies more on decision-makers' personal experience than on data-driven decision-making. Digital Twins (DTs), as advanced IT-based and data-driven decision-support systems, promise to improve decision-making processes, including exploration, execution, monitoring, and evaluation. This is particularly relevant in sustainability-related contexts, involving multi-attribute and multi-stakeholder decisions. This study examines the challenges that real estate managers encounter when making strategic decisions, while highlighting identified needs and opportunities for DT-supported decision-making, as well as barriers to their deployment. Drawing on practical insights from twelve semi-structured, problem-centred expert interviews with thirteen real estate professionals in Austria and Switzerland, analysed through qualitative content analysis, the findings reveal six challenge clusters – organisation, resources, data, applications, processes, and the real estate object – each comprising interconnected challenges from which relevant goals, threats, and opportunities for DT-supported decision-making can be derived. The gap between the promise of DTs and their actual use in REM underscores the tension between technological potential and realised value in practice.

Keywords: Real Estate Management · Digital Twins · DSS

1 Introduction

The EU's Green Deal [14] is a central element of the Union's strategy to achieve climate neutrality by 2050. The Architecture, Engineering, Construction and Operation (AECO) sector is among the domains addressed by the Green Deal, as it contributes significantly to global energy-related CO_2 emissions [21]. The

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sector covers the professionals, processes, and technologies involved throughout the life cycle of buildings and infrastructure within the built environment [9]. Given the low rate of new construction in Europe [19], the fact that 85–95% of today's building stock is expected to remain in use by 2050 [33], and the inefficiency of much of the existing stock [15], the European AECO sector is increasingly focused on the sustainable management and renovation of existing buildings. Policy measures such as the Energy Performance of Buildings Directive (EPBD) [13] intensify the pressure on real estate owners, investors, portfolio and asset managers, and public institutions to adopt environmentally, economically and socially (EES) responsible strategies aligned with the transition to climate neutrality [36,44]. At the level of individual buildings, decision-makers must determine an appropriate strategic direction based on factors such as building condition, location, and long-term value. These decisions may involve renovation, refurbishment, adaptive reuse, extension, dismantling, or divestment, thereby shaping a building's future role and potential.

From an information systems engineering perspective, sustainability-related Real Estate Management (REM) decisions constitute a complex, multi-attribute, multi-stakeholder space that can benefit from advanced information systems, such as Digital Twins (DTs). Decision-makers must balance EES objectives with regulatory constraints, risk-return expectations, and the interests of owners, tenants, financiers, and public authorities across multiple time horizons. In REM, decision-making occurs in a fragmented setting of heterogeneous, poorly integrated systems, making holistic support difficult and sometimes favouring inaction. In this paper, decision-making refers to the exploration, comparison, selection, monitoring, and revision of interventions for existing buildings, spanning the operational phase, short- to medium-term planning, and end-of-life decisions.

DTs, understood as modular, data-driven decision-support systems, can support decision-making in this context by integrating heterogeneous life cycle data, enabling continuous monitoring, and facilitating scenario analysis, forecasting, and what-if exploration. The interviews revealed recurring use cases for such decision support, including: (1) Comparing alternative interventions, including different material options, by simulating their long-term environmental, operational, and financial implications and their ability to support compliance with sustainability-related regulations, and (2) linking planned measures with monitored operational performance to compare expected and realised outcomes, enable performance evaluation, identify deviations early, and revise planning guidelines, measure catalogues, and prioritisation decisions accordingly.

The desired decision support goes beyond simply providing more data. It also helps decision-makers structure alternatives, compare intervention paths transparently, make assumptions and trade-offs explicit, and revisit decisions as conditions evolve. Such decisions are often not well-bounded optimisation problems but instead exhibit characteristics of wicked problems [40]. Addressing them may therefore require not only improved support within existing routines but also reflection on the underlying assumptions that guide action, echoing Argyris's distinction between single- and double-loop learning [1,2].

Empirical evidence from DT initiatives in REM and related domains indicates that their implementation remains challenging. Jahangir et al. [22] show that DT-based solutions struggle with fragmented and heterogeneous software landscapes, limited interoperability, and a lack of a unified cross-organisational approach. The integration of DT technology with existing tools is further complicated by compatibility issues and technical integration difficulties [3], as well as limitations in connecting building systems and Internet of Things (IoT) devices, which restrict real-time insight and control [39]. Lacking a unified approach, fragmented data management, duplicated efforts, and inconsistent decision-making undermine digital transformation initiatives [22]. Moreover, organisations often lack the expertise and support needed to implement and operate DT systems effectively [37]. Integration and capability gaps interact with complex interdependencies between new technologies and existing practices, leading to increased uncertainties, unreliable predictions, and poor management decisions due to limited understanding of how advanced tools perform in spatio-temporal dimensions [39].

With this in mind, the *present study* examines decision-making in a restricted subset of sustainability-oriented REM contexts, to identify where decision-makers experience pain that could plausibly be alleviated by DT-based decision support, and under what conditions such support can become effective. In line with this, the paper addresses the following research questions:

RQ1. What challenges do real estate managers face in the decision-making of existing buildings in the context of sustainability requirements?

RQ2. What DT-based support is required to effectively address these challenges?

From an information systems engineering perspective, this paper deepens understanding of the problem space surrounding DT-supported decision-making in this context, including the challenges decision-makers face and the conditions that shape its role. As such, this paper represents an initial step in a broader design science effort (see Sect. 3).

To address the above research questions *empirically*, we conducted twelve semi-structured interviews with real estate managers and analysed the transcripts using qualitative content analysis. We identified six challenge clusters in which sustainability-related difficulties emerge and shape decision-making processes. These insights provide an empirical foundation for understanding where and under what conditions DT-based support may be relevant in this context.

The remainder of this paper is organised as follows. Section 2 discusses the background and related work. Section 3 visits the research methodological aspects. Section 4 presents the identified challenges across the six areas. While Sect. 5 reflects on these findings, their implications, and the role of DTs. Finally, Sect. 6 outlines our next steps and concludes the paper.

2 Background and Related Work

REM encompasses the strategic, tactical, and operational activities involved in the development, operation, and transformation of individual properties and real estate portfolios on behalf of their owners [16,41]. A distinction is made between *portfolio management*, which defines the portfolio strategy and the capital allocation across assets, and *asset management*, which translates these strategic objectives into property-specific decisions. *Property and facility management*, in turn, are responsible for the operational use and maintenance of buildings and provide feedback on the condition and performance of existing building stock [45]. Together, these management functions shape decision-making throughout the operational phase of the building life cycle [20].

REM decision-making takes place in a multi-actor environment involving stakeholders beyond the management levels, including building operators, service providers, technology vendors, technical planners, consultants, building services engineers, public authorities, tenants, and occupants. These actors rely on a wide range of information systems, e.g., for planning (Building Information Modelling [BIM]), operation and maintenance (Computer-Aided Facility Management [CAFM] and Computerised Maintenance Management System [CMMS]), monitoring (Building Management System [BMS] or IoT platforms), and reporting and financial control (Enterprise Resource Planning [ERP] systems such as SAP, as well as spreadsheets used for ad hoc analysis and reporting). In practice, these systems are often heterogeneous and poorly integrated, making holistic decision support across organisational boundaries difficult and, in some cases, favouring inaction when responsibilities and expected benefits are unevenly distributed.

Growing *regulatory requirements for the sustainability of building stocks* – including, among others, the Energy Performance of Buildings Directive (EPBD), Corporate Sustainability Reporting Directive (CSRD), Sustainable Finance Disclosure Regulation (SFDR), and the EU "*Fit for 55*" package as well as certification schemes such as the German Sustainable Building Council (DGNB) and counterparts[1] within the DACH[2] – further increase the pressure to align existing building stock with climate goals.

Beyond these regulatory drivers, prior research has examined barriers and pain points that complicate the adoption of sustainable buildings [10], with particular emphasis on sustainable renovation [5,38]. Studies on building renovation identify bottlenecks at different stages and types of interventions [12,24,34], and group them into institutional and political, market and economic, financial, technical, behavioural, and social categories [5,23,34]. To make renovation more sustainable, [25] calls for a holistic understanding of sustainability that jointly considers social, economic, and environmental dimensions rather than optimising isolated criteria. Yet, such multidimensional assessments are often hindered by fragmented and unstructured information, as well as a lack

[1] ÖGNI (Austria) and SGNI (Switzerland).
[2] Germany (D), Austria (A), and Switzerland (CH).

of consensus on evaluation criteria, methodologies, and decision support [28]. In parallel, several contributions highlight a persistent lack of simple, holistic, and easy-to-use tools to support stakeholders' decision-making, especially in the early phases of renovation projects under high uncertainty [24]. While DT-based approaches promise richer data and continuous monitoring, current applications mainly focus on building robust data infrastructures and sensor integration [50] rather than providing explicit mechanisms that guide or structure decision-making processes [35]. Existing Decision Support Systems (DSS) based solutions focus on investment and valuation problems, whereas disciplines such as facility and property management remain underrepresented [29]. These challenges are longstanding, as early work on DSS and expert systems for real estate already identified limited use of available technologies, low acceptance in practice, and difficulties in integrating qualitative and quantitative criteria as key inhibitors of adoption [48].

Taken together, prior research points to a persistent need for integrated, practice-oriented decision support in REM that operationalises sustainability objectives across fragmented organisational and information-system landscapes. This appears particularly relevant for the operation of existing buildings and for short- to medium-term planning, where the practical role of DTs is still insufficiently understood.

3 Research Methods

This paper is part of a broader design science research effort to develop a methodologically grounded DT solution for REM. Following Johannesson and Perjons [26], the present study contributes to the transition from an initial to an explicated problem. At this stage, the goal is to develop a deeper understanding of the problem space of sustainability-related decision-making in REM and identify the challenges and conditions that may inform subsequent design activities.

In line with this exploratory objective, we conducted 12 semi-structured, problem-centred expert interviews. This form of *qualitative data collection* was chosen to capture domain-specific expertise while allowing sufficient flexibility for individual perspectives and context-specific experiences. The interview protocol was developed based on [4,47]. This combination of structure and openness ensured that all relevant topics were addressed while enabling the inclusion of emerging themes [47]. The problem-centred approach [11,51] supported a deductive-inductive procedure by incorporating both narrative-generating and comprehension-generating questions.

The *data sample* comprised 13 real estate professionals with asset- and portfolio-management responsibilities, interviewed in 12 sessions conducted either in person or via Zoom between October and November 2025. Participants were invited via email and LinkedIn based on their actual decision-making responsibilities in REM rather than their formal job titles, to ensure direct relevance to the research questions. While the interviewees held comparable roles, they represented different organisational contexts (see Table 1). These contexts differ primarily in their objectives: funds treat real estate mainly as an investment asset, CREM refers to corporates (C) in which real estate is a non-core activity, and REM refers to contexts in which REM itself is the core business. Six participants were based in Austria and seven in Switzerland. Although Switzerland is not part of the EU and is therefore not directly subject to the Green Deal, Swiss organisations pursue comparable sustainability goals, for example, through SGNI certification, which is based on DGNB standards. The empirical focus of this study is therefore a restricted subset of REM contexts, namely sustainability-related decision-making for existing buildings, viewed primarily from the perspective of asset and portfolio management in Austria and Switzerland.

In terms of *research quality*, the study aimed for relevance, transparency, and sufficient empirical depth. The sample was selected to cover participants with direct decision-making responsibilities in REM, thereby ensuring a close fit between the empirical material and the research questions. In addition, the study reached theoretical saturation. Hennink and Kaiser [18] report that saturation in qualitative studies typically occurs within 9 to 17 interviews. After conducting 12 interviews, the material provided sufficient depth and breadth of insights to meet the research objectives, while thematic repetition also became apparent after approximately ten interviews.

For *data analysis*, we employed a qualitative content analysis of the interview transcripts, based on the approach outlined by [30]. The analysis comprised three main steps: (1) an initial reading of all transcripts to gain an overall understanding of the material and to note first thematic impressions, (2) the development of a category system that combined deductive categories derived from our research questions with inductive categories emerging from the interviews, and (3) the iterative refinement and hierarchical structuring of these categories through continuous comparison. The resulting categories were grouped into six overarching challenge clusters that capture where sustainability-related difficulties arise for real estate managers within the enterprise (see Sect. 4). Coding and category development were supported using MAXQDA, which facilitated the systematic documentation of category definitions, coding decisions, and category revisions, thereby supporting traceability and consistency throughout the analysis [42]. The coding was performed by the first author. In addition, reviews between the co-authors on identified statements, assigned codes, and emerging categories helped to challenge interpretations, clarify category boundaries, and reduce the risk of intraobserver inconsistencies. Instead of conducting independent double coding and formally assessing interobserver disagreements, exchanges among the co-authors strengthened the analytical consistency of the study and contributed to its reliability and validity.

Table 1. Organisational contexts of the interview participants

IP	Category	Real Estate Portfolio Size			Country
		Number	Amount €	Floor area m^2	
E1	Fund	11	700 million	-	Austria
E2	REM	14'300	1 billion	-	Switzerland
E3	CREM	1'180	7 billion	-	Switzerland
E4	CREM	-	-	120'000	Austria
E5	CREM	350	6 billion	-	Switzerland
E6	REM	6	-	-	Austria
E7/8	CREM	3'000	-	-	Switzerland
E9	CREM	1'000	-	-	Switzerland
E10	Fund	-	8 billion	-	Switzerland
E11	REM	450	-	-	Austria
E12	REM	1'500	-	-	Austria
E13	REM	200	-	1.3 million	Austria

4 Findings

In the following, we present the results of the interviews with the 13 experts (E1–E13). We focus on challenges as identified by the real estate managers concerning sustainability requirements in relation to existing buildings (RQ1) as well as their initially identified needs regarding IT-based support for decision-making (RQ2). The challenges are grouped into six interdependent clusters (see Fig. 1), reflecting that the identified issues do not occur in isolation but interact in ways that directly and indirectly shape sustainable decision-making within organisations. These six clusters are defined as follows: *(1) Organisation* refers to the strategic orientation of the enterprise, its culture, structures, and allocation of responsibilities. *(2) Resources* concern the availability of personnel, expertise, time, and financial means. *(3) Data* describes the availability, completeness, structure, and accessibility of data. *(4) Applications* refer to the IT systems and digital tools that consolidate and analyse data, offering functions for decision-making. *(5) Processes* cover the workflows, procedural steps, and methods used to prepare, assess, and validate decisions. *(6) Object* relates to the physical building itself.

4.1 Organisation

Several interviewees emphasised that they **embedded sustainability in their enterprise culture** and that it has become an integral component of their corporate identity, rather than an isolated operational response to recent ESG (Environmental, Social, and Governance) regulations. This is forced by group-wide sustainability strategies and initiatives that apply across all business units, including real estate. Such overarching commitments function as an intrinsic driver. They reflect a conscious organisational choice rather than a reaction to immediate regulatory pressure. From a self-determination theory perspective, this can be understood as an internalised and integrated regulation of sustainability goals, which are experienced as self-endorsed rather than externally

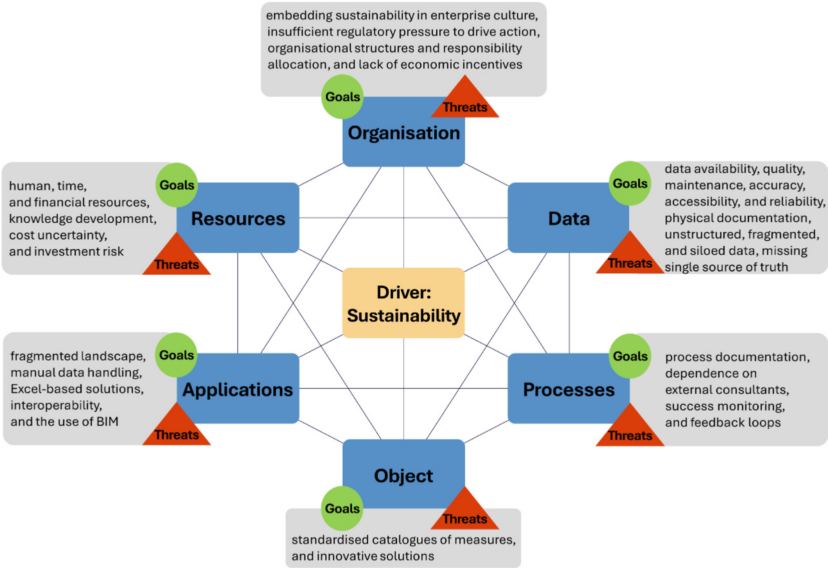

Fig. 1. Overview of the six challenge clusters

imposed [7]. Interviewee E6 contrasted such long-standing ambitions with organisations where sustainability is overshadowed by short-term yield considerations, remarking that *"the main focus at the end of the day is still on return. ESG is not necessarily in the foreground when other problems feel more urgent"*. In terms of self-determination theory, this points to a tension between extrinsic, financially oriented goal contents and more intrinsic, other-oriented sustainability goals [7]. These tensions become particularly relevant when sustainability targets require investments that cannot be justified purely on financial grounds.

Particularly those interviewees from organisations in which sustainability is not yet embedded in the corporate culture, highlighted **insufficient regulatory pressure to drive action**, arguing that the current regulation does not force organisations to initiate comprehensive investment programmes. E2 explicitly described a *"wait-and-see"* attitude among owners, stating that *"until the national renovation plan really arrives, many owners will do as little as possible and rather sell off the worst assets"*. This is consistent with the persistent uncertainty, highlighting the lack of stability and clarity in the evolving set of EU directives. In the absence of strong regulatory signals, senior management remains under limited pressure, which in turn means that sustainability concerns are not consistently translated into operational priorities further down the organisation.

Beyond regulatory exposure, internal **organisational structures and responsibility allocation** influence how sustainability-related decisions are made. Three recurring constellations emerged: (1) organisations with high exposure have established dedicated sustainability roles or units, (2) the governance model for property and facility management (in-house vs. outsourced) strongly affects data availability, operational insight, and the ability to identify issues at the object/asset cluster, and (3) effective implementation depends on clear responsibility allocation, well-defined data interfaces and ownership, and close collaboration between internal teams and external partners.

All of the above challenges are closely linked to resource-intensive investments (see Sect. 4.2). Such investments must be justified within the logic of a business case for sustainability. A recurring theme across the interviews is the difficulty of presenting sustainability investments as an attractive business case, especially in rental housing where the landlord-tenant split dominates, and capital expenditures cannot be fully passed on to tenants through higher rents due to regulatory, market, and social constraints. As long as there is a **lack of economic incentives**, adoption is likely to remain limited, as only a minority of actors will invest in sustainability measures in the absence of a clear economic rationale.

4.2 Resources

A recurring theme across all 12 interviews concerns the limited availability of **human resources with specialised know-how**. For example, regarding sustainability, associated regulations, or BIM. Organisations can respond by recruiting additional personnel, upskilling existing staff, or engaging external consultants. The latter, however, raises concerns: E1 remarked that *"everyone is offering ESG consulting, but with highly varying levels of quality and content"*. There is also a strong need for continuous **knowledge development and training** to keep pace with evolving regulations, technologies, and digital tools. Training is not limited to specialists – real estate managers must understand both sustainability requirements and the use of BIM and other tools, and that lessons from completed projects need to be systematically integrated into updated guidelines. Across organisations, **time constraints** limit the number of options that can be examined in depth. Decision-makers manage large portfolios and have little capacity for extensive scenario analyses or complex tool usage, which reinforces reliance on standard measures.

Financial resources and budgeting cycles further shape what is feasible: when a renovation is not budgeted, *"nothing will be done, no matter what the building needs"*, and annual, object-by-object planning reduces flexibility. High upfront costs for deep refurbishments and advanced building technologies are difficult to reconcile with short-term return expectations, while **cost uncertainty and investment risk** add to the reluctance to act. Early decisions rely on rough cost estimates, and interviewees highlighted the risk of mis-investments in technologies or materials that may later be restricted. E5 argued for condition-based assessments and learning from empirical data instead of purely normative replacement cycles, while E11 underlined the importance of tools that simulate alternative investment paths and associated sustainability impacts so that scarce funds can be directed to the highest combined economic and environmental benefit (Sect. 4.4).

Overall, these resource related challenges demonstrate that, beyond data and tools, sustainability decisions are tightly constrained by organisational capacity, time, and budgets, creating a strong demand for IT support (and potentially DTs) that reduces manual effort, improves transparency on trade-offs, and helps make better use of limited resources.

4.3 Data

Across all interviews, **data availability and quality** emerged as prerequisite conditions for sustainable decision-making in REM, yet also as persistent barriers. While newer buildings often have a substantial share of information available digitally, older assets still rely on historically grown, physical documentation, particularly paper-based drawings and plans. Most interviewees reported that these documents have largely been digitised through scanning. However, a small portion remains purely physical and is expected to be converted over the coming years. In contrast, information on ongoing changes to the asset, as well as invoices and service documentation, is typically stored digitally, within organically grown folder structures that are functional but not necessarily standardised or systematically maintained.

A recurrent issue is the predominance of **unstructured or semi-structured data** (e.g., PDFs and scanned records) distributed across multiple repositories and systems. Several interviewees, therefore, highlighted the potential of improved search and extraction capabilities to make such documents more usable. At the same time, critical technical details – such as insulation thicknesses or material assemblies – often still need to be requested manually from project partners or reconstructed from legacy documentation, since this information is neither captured in structured enterprise systems (e.g., SAP) nor consistently and up to date in CAFM or BIM environments. Limited data maintenance and the large number of stakeholders involved, from whom REM receives inputs (including BIM models), further contribute to uncertainty about whether datasets remain up to date. Some interviewees described a resulting loss of trust in data reliability, which can lead to deliberate non-use of available data due to validity concerns.

Interviewees also stressed the importance of understanding data sources and data use across the building life cycle. Data are generated, modified, and required in every life cycle phase. Consequently, organisations need clarity on when specific data are created, where they are stored (e.g., BIM, CAFM, project repositories), and for which activities they are necessary. Such lifecycle-oriented data governance is also linked to the reduction of data silos and the centralisation of key datasets into a single source of truth. Importantly, interviewees noted that "more data" is not automatically better: decision-making benefits from purpose-driven data selection, including transparency on which data are available internally and which must be sourced externally, and a clear understanding of the added value of each dataset. These efforts are further complicated by constrained data access – most notably tenant consumption data – which is relevant for decarbonisation planning and investment decisions but is often unavailable to REM.

Finally, data flows from operations to strategic decision-making were frequently described as fragmented and highly manual. This pipeline is labour-intensive, delay-prone, and susceptible to errors, while operational data from CAFM systems is only partially integrated into portfolio-level planning. Accordingly, interviewees expressed a strong need for more automated and standardised data pipelines into central data platforms that can support both reporting requirements and robust decision support.

4.4 Applications

The interviews paint a **fragmented picture of the digital applications** used, with CAFM, ERP systems (e.g., SAP), specialised energy monitoring tools, and various Excel-based solutions often coexisting side by side. In many organisations, central tasks continue to rely heavily on manual data export and subsequent consolidation in spreadsheets. E11 summed up this situation: *"Currently, everything is very Excel-based, we pull data from different systems and combine it in a list to create a plan."* More than half of those interviewed reported working with multiple systems in parallel, with limited interoperability. This leads to "media breaks", duplicate data entries, and inconsistent data views. E3 pointed out that organisations often try to cover "all possible eventualities" with their tools without defining clear use cases, which further increases complexity and makes everyday handling more difficult. Against this backdrop, several interviewees expressed a desire for an integrated solution that supports different levels of abstraction and, at the same time, provides scenario analyses and simulations as decision support. Such functions are considered particularly relevant where they are currently either not available at all or only used selectively (e.g., for specific analyses such as energy flows).

In the cases examined, BIM plays a complex and ambivalent role. Several of the organisations surveyed use BIM as the central basis for planning and construction in new building projects. However, the perceived benefits are much more controversial when it comes to the transition from the construction to the operational phase and, in particular, when dealing with existing buildings. Several interviewees pointed out that BIM has only gained noticeable importance in their practice in the last five years. Buildings constructed before that time generally do not have a BIM model, but continue to rely primarily on traditional planning documents. E5 reported that BIM is used primarily for larger renovations, serving more as a kind of "encyclopaedia" for looking up which components were installed, rather than as a fully integrated system for operation. The **sustainable use of BIM** in the operational phase was cited as a key challenge: *"the ongoing maintenance and updating costs are high, and the benefits in relation to the resources required are not always clear"*. E7/E8 added that the costs of recording existing buildings have decreased significantly in recent years, so they would like to wait and see how the market develops. At the same time, they were cautious about broad-based data collection as long as processes, roles, and target systems were not clearly defined in organisational terms. Overall, this underlines that the value of BIM – especially as a data source for sustainability-related decisions – depends heavily on organisational maturity, clear responsibilities, and integration into existing systems and processes.

4.5 Processes

Across the cases studied, internal checklists and guidelines (structured process documentation) emerged as central instruments for embedding sustainability requirements into everyday project work. E5 reported that their organisation uses internal checklists and a catalogue of approved materials that specifies which substances may be used and which recyclability requirements must be met. Similarly, E7/E8 and E10 describe internal planning guidelines derived from external standards (e.g., the Swiss Sustainable Construction Standard [SNBS]), which translate overarching sustainability principles into concrete and verifiable project requirements. In addition, E11 highlighted ongoing efforts to digitise building conditions and technical due diligence reports in order to link them more systematically to refurbishment planning and investment decisions.

Where internal guidelines and capabilities reach their limits, organisations frequently rely on external decision support. Given the complexity of regulatory requirements and technical solution options, external consultants play a key role in sustainability-related decision processes. E1 described a growing reliance on ESG advisors, for example, for photovoltaic (PV) projects and taxonomy assessments, while also emphasising a major challenge: *"the market offers highly heterogeneous services in terms of quality and content, making it difficult to assess what is provided for which fee. Consultants typically support the preparation of decision documents, conduct market soundings, and develop variants. However, their outputs still need to be critically reviewed internally and integrated into the organisation's own investment calculations"*. The majority of interviewees also reported engaging external experts for specialised tasks such as climate-path modelling, taxonomy conformity checks, and life cycle assessments. While this brings in expertise that is difficult to maintain in-house, it also creates dependencies and adds another layer of coordination in an already complex process. A further recurring challenge concerns **monitoring the success** of sustainability measures. Several interviewees noted that improvements are often evidenced by updated energy performance reports, which document how building performance has evolved. At the same time, feedback on realised performance rarely re-enters earlier planning phases in a structured way, which limits organisational learning. Accordingly, interviewees saw potential in more systematic feedback loops that connect measured performance and monitoring results with planning guidelines, measure catalogues, and prioritisation processes.

4.6 Object

Many organisations rely on **standardised catalogues of measures** when planning sustainability interventions. Across the interviews, experts consistently described a set of roughly ten measures (e.g., envelope improvements, window replacement, roof insulation, PV installation, heating system replacement) that are routinely assessed and combined depending on object-specific analyses. E13 pointed to an industry discourse to focus on "the same ten measures" across projects and emphasised a potentially self-reinforcing pattern: *"organisations repeatedly fall back on familiar options, while alternative approaches are rarely explored – such as an "eleventh option" that could be cheaper, less intrusive, and still equally effective in reducing* CO_2*."* E1 and E3 echoed this concern, noting that novel combinations of measures or innovative solutions may be overlooked when decision-makers follow established templates without systematically evaluating alternatives. This highlights a key tension: standardised catalogues support efficiency, reproducibility, and comparability, but they may also constrain explorative thinking and hinder the identification of more context-specific or innovative sustainability solutions.

5 Discussion

Synthesis of the findings – We use Goal-Oriented Requirements Engineering (GORE) following Van Lamsweerde [31,32] to synthesise the findings. GORE is suitable in this context because it provides a traceable way of relating stakeholder intentions, goals, and obstacles. The resulting goal model, see Fig. 2, is represented using ArchiMate's motivation extension [46] and was created with Archi[3].

In the model, *sustainability* is treated as the central *driver* shaping decision-making in REM. Investors and real estate owners can either support or constrain sustainability ambitions, while legislators exert strong external pressure through regulation. In this context, the overarching goal (G0) is defined as: *enable data-driven sustainability decision-making for existing buildings*.

The synthesis makes explicit what REM organisations aim to achieve, represented as goals (G) in green, and which threats, shown in red (T), hinder the achievement of these goals. Accordingly, the findings are structured into the six clusters *Organisation* (G1/T1), *Resources* (G2/T2), *Data* (G3/T3), *Applications* (G4/T4), *Processes* (G5/T5), and *Object/Building* (G6/T6).

At this stage, the model remains intentionally high-level and serves as an intermediate abstraction between the empirical findings and later requirements-oriented design work. In future work, the goals will be refined in greater detail, particularly with regard to the interdependencies between the clusters already indicated in Fig. 1. This refined structure will then support a more explicit translation into requirements, architectural choices, and design principles for DT-based decision-making solutions.

Learning Loops in sustainable REM – The findings can be interpreted through single-, double-, and triple-loop learning [1,2,17]. While single-loop learning (SLL) adjusts actions to predefined targets, double-loop learning (DLL)

[3] https://www.archimatetool.com/.

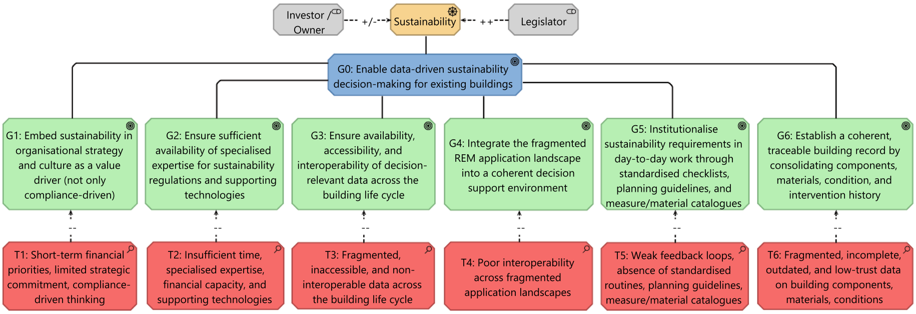

Fig. 2. Motivation Viewpoint representing the Goal Model

revises the underlying assumptions and targets, and triple-loop learning (TLL) reflects on the broader organisational purpose shaping them.

Most sustainability practices in REM currently remain in an SLL. Energy monitoring, certifications, climate-path tracking, and internal guidelines primarily serve to demonstrate compliance and to trigger standard measures from established catalogues. When deviations occur, responses focus on improving execution rather than questioning objectives, strategies, or the underlying logic of measurement catalogues. DLL becomes visible when organisations reconsider asset strategies, planning guidelines, or risk–return expectations. TLL emerges when organisations redefine their role in the transition to climate neutrality. For instance, some interviewees (E3 & E10) reported strategies that explicitly position the organisation as a sustainability frontrunner, even if this implies longer payback periods, higher short-term risks, or tensions with established yield expectations.

These learning loops imply distinct requirements for DTs. Supporting SLL requires capabilities for forecasting, scenario comparison, early warning, and ex-post evaluation of realised versus expected outcomes. Supporting DLL requires making alternative assumptions and their portfolio-wide implications transparent. Supporting TLL requires enabling the exploration of alternative futures and value positions, including their effects on strategic options, risks, and pathways.

Taken together, the findings not only identify challenges in REM practice but also inform the design of DT-based decision-support systems. They suggest that such systems should be designed as modular socio-technical decision-support infrastructures that combine (1) integrated and purpose-driven data provision, (2) scenario and simulation capabilities for comparing alternative intervention paths, (3) support for ex-ante and ex-post evaluation and feedback loops, and (4) explicit representation of assumptions, trade-offs, and stakeholder perspectives. In this sense, the six challenge clusters can be understood as a practice-grounded requirements structure for DT engineering in sustainability-oriented REM.

Between heuristic judgement and analytical reasoning – A complementary view for interpreting these findings is *dual-process theory* [27]. Several patterns point to a tension between fast, experience-based, heuristic judgment and slower, more deliberate, analytical reasoning. In sustainability-related REM decisions, time pressure, limited organisational capacity, fragmented data, and uncertainty about costs, regulation, and long-term effects make reliance on familiar measures and established routines understandable. At the same time, the interviews show a need for more systematic comparison of alternatives, clearer representation of assumptions and trade-offs, and simulation-based exploration of future consequences. From this perspective, DT-supported decision-making is valuable not only because it provides more data, but because it supports more reflective and transparent analysis when needed. Rather than replacing professional experience, DTs can complement it by making alternatives comparable, questioning taken-for-granted options, and enabling more context-sensitive solutions.

From tame to wicked problems – Rittel and Webber [40] distinguish between *tame* problems, which are well-bounded and solvable under stable assumptions, and *wicked* problems, which involve conflicting objectives, uncertainty, and no single optimal solution [40].

Assessing sustainability in real estate cannot be reduced to a single project phase or a cost-efficient process step. It concerns the building as an object, together with its entire life cycle. It requires a choice of system boundaries and time horizons, balancing operational and embodied emissions, financial returns and affordability, and revisiting these judgements as regulation, technologies, and user needs evolve. Rather than being solved once and for all, the "sustainability" of an object needs to be continuously renegotiated along its transformation path. The sustainability of a particular building over its life cycle and their circularity [8], therefore, quickly takes on the characteristics of a wicked problem.

For such problems, DTs are essential. Because relevant knowledge is distributed, partly tacit, and socially shaped [43], DTs can integrate heterogeneous data, make assumptions and trade-offs explicit, support stakeholder discourse, and enable structured exploration of alternative development paths. In such a context, information systems should be conceived less as optimisation engines for a fixed problem but rather as socio-technical infrastructures that support practitioners to understand, navigate, and govern the wicked decision space around the life cycle sustainability of individual objects.

Limitations of the present study – Like any qualitative study, this work is subject to limitations in scope and generalisability. It focuses on REM professionals in Austria and Switzerland and therefore does not claim statistical representativeness for the broader European real estate sector. The portfolios considered are primarily comprised of residential and corporate buildings. More complex asset classes, such as hospitals, hotels, or shopping centres, with different technical profiles and renovation cycles, are largely absent. The identified challenges and IT requirements may only partially transfer to these contexts. The analysis mainly reflects the perspective of owners' asset and portfolio management units, while other key actors, such as facility and property managers, external service providers, regulators, technology vendors, and tenants, were not systematically included, which may bias the identified pains towards strategic and financial concerns.

6 Conclusion

This paper contributes to Information Systems Engineering by structuring the problem space of sustainability-oriented decision-making in REM. From an information systems engineering perspective, the paper develops a deeper understanding of the requirements for DT-based support in this context, as well as of the constraints shaping its actual development. The findings show that effective DT-based decision support in REM depends not only on technological capabilities, but also on organisational conditions, procedural embedding, and the availability and integration of decision-relevant information.

More specifically, the six identified challenge clusters point to concrete classes of requirements for DT-based decision support, including integrated and interoperable data provision, modelling and simulation capabilities, feedback and learning mechanisms, and support for making assumptions and trade-offs explicit. In this way, the paper provides a practice-grounded basis for subsequent requirements-oriented and design-oriented work on DT-enabled decision-support systems in REM.

In *future work*, we will refine the goal-oriented requirements engineering perspective developed in this paper in order to derive a coherent DT functionality profile aligned with stakeholder goals and value propositions. We also plan to assess adoption-relevant factors and the perceived added value of DT-based decision support in practice through a quantitative survey grounded in the Technology Acceptance Model (TAM) [6] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [49]. In doing so, we aim to complement the qualitative insights with more generalisable evidence on acceptance and usage intentions.

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