

Research and evidence-based standards paving the way for digital and sustainable transformation of the built environment

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Abstract:

Purpose

Researchers and standardisation bodies are key to accelerating societal transition and contributing to society's demands for sustainability, resilience and digitalisation. Standards are the agreed-upon best practices published by national or international bodies and are key enablers of transformation. Scholars have not yet identified a relationship between standards and facilities management (FM) research. The purpose of this article is to investigate the role of formal standards in FM research.

Design/methodology/approach

A literature review was conducted to identify journal articles addressing standards and FM. A total of 198 journal articles published from 2010 to 2021 were identified. After screening these articles, 27 journal articles were considered the most relevant for data analysis.

Findings

The findings show that the role of standards in research can be analysed thematically, categorically, textually, methodologically and directionally. Standards are relevant to research by defining terms, creating backgrounds, guiding research, supporting the development of new standards and encouraging more collaboration between research and standardisation. Some studies have shown how standards influence research, but only a few have explored how research influences standards.

Originality

The articles collected and analysed in this study comprise original research. A limited preliminary study of ten core articles was presented at the International Council for Research and Innovation in Building and Construction (CIB) World Congress 2022. This presentation of our work provides an expanded framework for analysing the roles of standards in research. This framework includes (1) categorical analysis of research and standardisation streams; (2) thematic analysis of the topic of interest; (3) textual analysis of the use of the term 'standard'; (4) methodological analysis of the influence of standards on the research method and (5) directional analysis of the intended audience.

Research limitations/implications

This research provides examples that inspire stronger collaboration between people and processes in research and standardisation.

Keywords

Facility management, research collaboration, standardisation, sustainability, digital transformation, ISO 41000-series

1.0 Introduction

Standards for products, processes and management systems are important to the sustainable transformation of the built environment. Digital technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI) and edge computing, are important enablers for sustainable and circular transformation (Fraga-Lamas et al., 2021).

Sustainable transformation reflects the need to ensure humankind's longevity, and these sustainability efforts are increasing. For example, the International Organization for Standardization (ISO) mapped and categorised their standards using the Sustainable Development Goals (SDGs) to visualise and guide users on the standards that support specific goals and to 'help them to rise to the challenge' (ISO, 2021a). The SDGs are part of the 2030 agenda launched by the United Nations (UN) in 2015 and 'represent an urgent call for action by all countries—developed and developing—in a global partnership' (UN, n.d.) to ensure that the world is sustainable.

To accelerate sustainable transformation, the UN launched its Principle for Responsible Investing and coined in 2004 the term 'environmental, social and governance' (ESG) through its 'Who cares wins'-report (Billo et al, 2020; Pollman, 2022). The report aimed to increase 'the awareness of all involved financial market actors' (The Global Compact, 2004). ESG has become increasingly important for organisations in transforming their practices into sustainable and circular practices. ESG has not been standardised, but it positively affects firms and their market and financial performance (Ademi and Klungseth, 2022).

The European Union (EU) followed its ESG initiative with its Green Deal strategy pillar of sustainable finance (EU, n.d.) to force financial institutions and industries to think more deeply about the positive and negative impact they have on the world, particularly on society and the environment. The financial sector is important because it has unique power in financing the activities of other industries, and their failure to comply with new demands can result in missed opportunities and the loss of financing and lending support. This significantly affects facility management (FM) and the architecture, engineering and construction (AEC) industry. The new EU Taxonomy and EU Green Bond standard (EUGBS) raise the quality requirements for the practice, and research that examines how they influence AEC industry has increased. This has also led to the establishment of new global organisations focused on developing standards. For example, the International Sustainability Standards Board (ISSB) was established in November 2021 during the 26th Conference of the Parties meeting (COP26) as part of the International Financial Reporting Standards (IFRS) Foundation to 'harmonise sustainability metrics with global financial reporting requirements' (esg.tech, n.d.).

Data, such as ESG measures, and the use of digital technologies, through digitalisation, enable sustainable transformation (Fraga-Lamas et al., 2021). The EU refers to the combination of digital and green tools as the 'twin transition' (EU Science Hub, 2022). Considering this transition, the building and construction sector, which is part of FM, is considered one of the five most relevant sectors because it pollutes the most (Muench et al., 2022). In examining the key requirements for a successful twin transition, Muench et al. (2022) focused on the importance of daily building operations and FM, particularly in the future, and explained the following: 'The construction business is shifting from new construction to the management of existing buildings spaces. Facility management needs are growing...' (p. 38). To meet future needs, FM must embrace all possible means, including standardisation.

1.1 Standards as key enablers

The EU (EU, 2021) has focused on the importance of both standardisation and research efforts in combining the green and the digital by calling for twin transition research and development.

Standards are key enablers of this transition (EU, 2022) and represent one of three political factors required for it to be implemented at scale (Muench et al., 2022). This is important for FM. Improving and implementing international FM standards drives the sustainability of the built environment and the digital transformation of the entire AEC industry.

Clearly, FM plays a key role in the transition to a digital, sustainable and climate-neutral world. For example, a close relationship exists between the key parts of the definitions of FM in ISO 41001:2017 and sustainability in EN 17485:2021 (Klungseth et al., 2022). Both definitions use a wider scope by considering the economy, the environment and social aspects.

The COVID-19 pandemic highlighted FM's key role in society, as the virus ruled every part of the world from 2019–2022, a time known as the 'corona pandemic'. During this time, the role of facility managers was recognised for their important contribution in providing spaces, infrastructure and services to people and organisations. For example, in response to the COVID-19 pandemic, the Norwegian government included cleaners on its list of critical societal functions (Norwegian Government, 2021). Solutions helping the covid-19 situation were developed all over the world, including standards and technical reports, such as the publicly available specification (PAS) named ISO/PAS 45.005:2020 Occupational health and safety management—General guidelines for safe working during the COVID-19 pandemic. Additionally, organisations made helpful material freely available to the public. For instance, ISO's COVID response website (<https://www.iso.org/covid19>) listed standards to help organisations and the world fight COVID, including standards for protective gloves and clothing, lung ventilators, business continuity management systems, emergency management and community resilience.

1.2 Development of standards

The goal of standardisation bodies to enhance productivity and promote collaboration and innovation has a long history, which shows that the development and adoption of standards can be a slow process, particularly on a global scale, but it enables smooth collaboration.

For example, the development of the metric system involved a lengthy process. A total of 150 years passed from 1801–1965, during which the new standard was created and implemented and demonstrated its potential (Klungseth et al., 2022; Wenzlhuemer, 2010). Thereafter, standardisation bodies emerged around the world, and today, most countries and continents have standardisation bodies. Europe has three standardisation bodies (Wenzlhuemer 2010). Globally, four international standardisation bodies exist: ISO, the International Electrotechnical Communication (IEC) and the International Telecommunication Union (ITU) and the now also the ISSB (SBS, n.d.; esg.tech, n.d.).

An everyday example of standards that are relevant to productivity, innovation and collaboration is the use of ATMs, which most people consider an easy and obvious process. Standards ensure that all payment cards fit all ATM machines around the globe (ISO/IEC 7812-1:2017 and ISO 8583). Additional examples include paper size (ISO 216:2017), the functionality of blue ball pens (ISO 12757-1:2016), and USB cables and connectors in personal computers (IEC 62680-1-3:2022).

A digital and sustainable transformation of the built environment strongly depends on humankind's understanding of sustainability and the reasons for its importance, including the management of natural resources, the natural environment and the built environment, as well as social and economic dimensions. Facility managers play a crucial role in the digital and sustainable transformation, and education, research and standards that synthesise best practices are essential tools that facility managers can use to save time and money while improving the efficiency and effectiveness of FM outcomes.

1.3 Research and standardisation streams

Numerous standards govern the built environment, particularly regarding digitalisation, and even more are emerging. The amount of research and standard development involving concepts such as building information modelling (BIM), digital twins, and industry foundation classes (IFC) is so vast that it can be considered its own research and standardisation stream. Examples include studies that aim to enhance interoperability (Alavi et al., 2021; 2022), explore the opportunities of IFC objects and FM using the Semantic Web (Kim et al., 2018), open standards such as model view definition (East et al., 2013), or apply disruptive technologies for FM (Marocco and Garofolo, 2021), including its link to smart buildings and smart cities (Grübel et al., 2022). This stream can be referred to as *'the digital stream'*, which is a well-established stream that is highly relevant to the operation and management of buildings, including FM. These standards have a technical focus and are vitally important to digital FM as they track FM performance, including ESG (see e.g., EC-3's BIM standard overview, <https://ec-3.org/governance/technical-committees/modelling-standards-committee/>). The other research and standardisation stream that is relevant to this article is rather nascent and relates to standards within the FM domain. These standards focus on management and are referred to as *'the management stream'*.

The standardisation and research streams are connected. Management standards identify the information required for facility managers to manage efficiently (e.g., how to describe, develop and measure FM consistently worldwide). Standards of a technological nature relate to the digital transmission of information required in FM for different kinds of technological solutions. The research and standardisation streams can be characterised as a two-way challenge for FM practice in which both streams must be developed further and interlinked for FM to reach its full potential. Individually, both streams enable a more efficient and effective FM practice by improving quality and productivity. A third stream of research and standards relates to space measurement and building codes, regulations and standards and connects with these aforementioned streams. This stream is referred to as *'the technical stream'*.

This article primarily focuses on the management stream, which includes the standards developed specifically for the FM discipline, and the role of management standards in research. This article is particularly interested in standards developed by technical committees (TC) that specifically focus on FM, such as ISO/TC 267 Facility Management (for additional information, see <https://committee.iso.org/home/tc267>). Members of a TC who contribute to a working group (WG) developing a standard are referred to as *standardisation experts*. The authors of this article believe that it is vital to increase collaboration between FM practitioners, standardisation experts and researchers to continue to advance FM.

1.4 Purpose and research questions

This article aims to connect the knowledge triangle for developing FM, which considers education, research and practice/innovation as key elements in developing FM knowledge, skills, practices and theories/models (Haugen and Klungseth, 2017). This article also calls for theory development for standards relevant to FM, particularly the ISO 41000 series.

The purpose of this article is to investigate the role of standards in current research, particularly in building research, and to examine various methods by which researchers, research organisations and standardisation bodies can combine efforts for a sustainable and digital transformation of the built environment. Of this reason, this article address the following RQs: *What role do standards play in peer-reviewed journal articles, and do they substantiate the relationship between standards and research?*

Standards can be understood in many different ways. For example, there are management systems standards (MSS), product standards for electronic products, such as refrigerators and electric points, and process standards for welding processes, measurements and climate accounting.

The scope of this article is the relevance of MSS to FM. Product and process standards are outside the scope of this article. Examples of relevant MSS standards include the standards for the management of quality (ISO 9001), the environment (ISO 14001), energy (ISO 50001), assets (ISO 55001), occupational health and safety (ISO 45001), risks (ISO 31000), security and resilience for business continuity (ISO 22301) and FM (ISO 41001).

2.0 Research Methodology

Conducting a literature review is a natural starting point to gain insight into the ways in which research and standards influence each other in FM. Literature reviews provide insight into and a better understanding of previous research. To answer the research questions, a literature review was used because it can indicate how research publications have handled standards, and to some degree, it can explain how and to what extent research publications have influenced standards.

There are many forms of literature reviews, such as narrative, systematic, semi-systematic, meta-analytic and integrative reviews (Snyder, 2019). A systematic literature review (SLR) was considered the most appropriate methodology for this study because it can ‘identify all empirical evidence that fits the pre-specified inclusion criteria’s to answer a particular research question or hypothesis’ (Snyder, 2019, p. 334). The aim was to investigate the role of standards in peer-reviewed journal articles and to find evidence of their relationship to research, particularly global FM standards within the ISO 41000 series, such as ISO 41011:2017 Facility management—Vocabulary.

The literature review followed Nielsen et al.’s (2016) six steps for a systematic review. The purpose was to identify and examine different ways that research has influenced and enhanced past and future standards. The research for this article also aimed to develop a framework that explains how FM researchers in research organisations, such as ISO or the International Council for Research and Innovation in Building and Construction (CIB), can benefit from collaboration. All authors agreed that the focus should be on the use and operation of buildings.

The search process targeted research and review articles in two databases (ScienceDirect and Google Scholar) using two search strings containing the following keywords: (1) ‘standardisation’, (2) ‘facility management’, ‘facilities management’ or ‘FM’ and (3) ‘ISO’ or ‘ISO41000’. The first search string included only ‘ISO’, and the second string included ‘ISO41000’. Total 198 publications were identified through these searches and screened using several steps. Tables 1–4 and Klungseth et al (2022) provide a detailed description of the entire process. After identifying the building type, scientific domain, discipline and focus of the articles, the analysis narrowed down to the 27 most relevant articles by considering the frequency of the word ‘standard’ in each article.

The qualitative analysis of these 27 articles included a full reading of the articles and the grouping of the articles into four themes related to the purpose of this article. Table 4 describes the role of standard(s).

The quantitative analysis counted the number of times the term ‘standard’ appeared in each article and identified the section(s) in which the term was found. Specifically, the analysis examined whether the articles referred to ‘standards’ in the keywords, abstract, introduction, methods, results, or conclusion sections (see Table 5).

The hypothesis is that standards are predominantly mentioned as motivating factors and that the use of standards relates to the artifact under construction, e.g., a property or a digital model. Consequently, the expectation was that articles referring to standards in the introduction merely did so to define a term, whereas articles that focused on standards in their methods, results or conclusion sections used standards as a key element in their analysis. The applied methodology provided a transparent identification system for articles that exemplify FM-related research with an explicit reference to national or international standards.

Table 1. Categorisation examples from the first screening round

Article	Status	Reason for status
Gordon, A.M., Malik At and Kahn S.N (2021), Which patients are at risk for not receiving anti-osteoporosis treatment following hip fracture?: An ACS NSQIP analysis, Journal of Clinical Orthopaedics and Trauma, 20 March 2021	RED	Medical, no facility, facility services or standard focus
Kacso-Viderean, L., Nioeman, J. ...Pisla A. (2018), Change management Aspects in Solar Energy Implementation, Procedia – Social and Behavioural Science, 27 April 2018	YELLOW	About management and maybe sustainability, solar energy focus, no facility or standard focus
Matharneh, Danso-Amoak,... Matarneh R. (2019), Building information modelling for facilities management: A literature review and future research, Journal of Building Engineering 24	GREEN	About facility management

Table 2. Categorisation of the 48 journal articles in the second screening round

Building type	#	Scientific domain	#	Discipline	#
Unknown	25	Engineering and Architecture	34	<i>FM (facilities management)</i>	17
Health care facilities	9	Health and Patients safety	7	<i>Management and Standardization</i>	10
Industrial	7	Leadership and management	5	Construction (AEC/BCRE)	10
Public buildings	3	Social Science	2	AM (asset management)	5
Educational	1			People	4
Heritage	1			SM (service management)	1
Infrastructure/Service	1			Animals	1
Urban	1				
TOTAL	48		48		48

Table 3. Categorisation identifying the focus of the articles, part of second screening round

Third category	# FM	# MS	SUM
IT (BIM, IOT, DATA)	5	4	9
Quality, Certification and Standardization	2	2	4
Environment	2	1	3
Unknown	3	0	3
Health	1	1	2
People management	1	1	2
Indoor climate	1	0	1
Maintenance	1	0	1
Risk	1	0	1
Marketing	0	1	1
TOTAL	17	10	27

3.0 Findings

Table 4 presents the 27 articles and brief comments on the role of standards. Article No. 1 referred to 'standard' as many as 83 times in the full text, compared to Article No. 27, which mentioned 'standard' only once. Table 5 indicates when and where the term 'standards' was mentioned in each article. Generally, the term 'standard' was most frequently referred to within the chapters (e.g., theory, results or discussion chapters), thus illustrating that standards played a key role in these research articles.

Top	#	Authors	Journal	Description of the role of standard
1	83	Toledo et al (2014)	Computer Standards & Interfaces	Suggesting of an ITS standard to be considered by standardization organizations
2	60	Bieser et al (2020)	Property Management	Specific references to the 41000 series. Identifies a rich group of relevant laws, norms, standards and methods and suggest a framework for risk management at data centers
3	39	Jang and Collinge (2020)	Journal of Building Engineering	British standards for BIM is used and discussed throughout the paper. It sees the fact that there is a standard as a sign of some maturity.
4	34	Dzukififi et al (2021)	Journal of Building Engineering	Literature on what effects maintenance practices. Address ISO41001 specifically. Makes recommendations of a future concept for maintenance aligned with 41001. <i>(research intended to contribute to standard development)</i>
5	33	Ren et al (2019)	Journal of Building Engineering	Uses the term standard in relation to the need of standardized data for life cycle management for a building
6	26	Kairies-Alvarado et al (2021)	Energy and Buildings	No reference to FM standards, only energy efficiency standards and standards to calculate buildings carbon footprint in a life cycle perspective. Calculations was based on standard solutions e.g. standard density of a building material.
7	22	Amos et al (2019)	Property Management	State that the application of FM standards in academic research is limited and points to the need for standards for benchmark and performance metrics. But also the need for regional variations.
8	20	Maarneh et al (2019)	Journal of Building Engineering	Address the need for standardized processes for exchanging knowledge from a building project to FM systems and operation. Refer to the concept of standards including open standards like COBie. Refer to NIST (USA)
9	14	Akin and Björkstén (2017)	Construction Innovation	Direct reference to ISO41001. Talks about FM being a latecomer in standardization and the need of involving FM in the early stages of building processes. (soft landings). Interesting editorial article on construction innovation and standards.
10	13	Bortolini and Forcada (2020)	Building Research & Information	Refer to ISO41001 as the standard for a FM system and argue that there should be a focus on the end-users and their complaints, when designing a maintenance strategy.
11	12	Støre-Valen and Buser (2019)	Facilities	Direct reference to ISO41001. States that the researchers were aware of ISO41001 but were not aware that the practitioners (interviews) were using the standards. Lacks implementation.
12	12	Lyhne et al (2012)	International Journal of Medical Informatics	focus on the absence of a standard protocol on how to execute handover processes. Suggest a generic method with out detailed specification
13	11	Vukmirovic et al (2021)	Sustainability	cite text from ISO41001 and an american standard for indoor climate, but mainly the term standard refers to a political plan for deasent housing of an appropriate standard.
14	11	Troung et al (2018)	Journal of Destination Marketing & Management	suggest a standardised methods to describe tourist destination attributes
15	10	Dahanayake and Sumnarathna (2022)	Journal of Facilities Management	based on a literature review, this paper argue that standardisation of digital data/information is needed for digital transformation of FM. making use of IoT and BIM. standards are needed for effective use of
16	10	Rafiqdeen (2020)	International Journal of Sciences and Research	Argue that standardisation of FM services are more important for the quality of services than cost/umisation. Despite one reference to ISO41001, the research is focused on organisations own standards (a la SLA's)
17	8	Amponsah-Tawiah et al (2016)	Safety and Health at Work	Survey find strong link between safety leadership and mine workers turnover rates, refer to standard deviation etc
18	6	Kristl et al (2020)	Facilities	General use of the term standard and no specific references to eg ISO41001
19	5	Bröchner et al (2019)	Facilities	Direct reference to ISO41001. Critiques ISO41001 for lack of terms related to the impact on the environment. Mention sustainability standards
20	4	Raendran et al (2020)	(IACSA) International Journal of Advanced Computer Science and Applications	only general reference to standards. Focus on smart toilets
21	4	Nijkamp and Mobsch (2020)	Facilities	Refer to ISO41001 for definition of FM and mention european standardisation bodies 3 times.
22	4	Ehrenberg (2021)	Corporate Real Estate Journal	Discusses the influence of covid and current trends on outsourcing practices in CREM, mention ISO 41001
23	2	Kumar et al (2016)	Medical Journal Armed Forces India	the term standard is used only in relation to standardized documentation protocol for optimal medical store management
24	2	Manjore et al (2016)	Procedia - Social and Behavioral Sciences	SEM approach used to assess energy resilience, consistency and standardisation is seen as important KPIs
25	2	Krabbe(2019)	Corporate Real Estate Journal	Presents an FM process model. ISO 41001 was helpful for the global FM implementation process of the company Bayer
26	1	Janz et al (2021)	Facilities	in methodology section addressing standardised interview guides
27	1	Neurath et al (2012)	Transfusion and Apheresis Science	standardized plan to provide guidance to hospital personnelle in response to blood supply shortage (suggest a default plan instead of every one have to come up with a plan of their own)

Table 4. Top 27 articles ranked by the frequency (#) in the use of the term ‘standard’

Top	#	Authors	Abstr.	Keyw.	Intro	Theory	Method	Result	Disc.	Concl.	Ref.	Apx.
1	83	Toledo et al (2014)	4	1	10	17	0	13	1	11	9	17*
2	60	Bieser et al (2020)	1	0	1	0	3	In disc	39	4	2	10
3	39	Jang and Collinge (2020)	3	1	2	17	3	3	3	2	5	0
4	34	Dzulkipli et al (2021)	1	0	3	23	0	2	2	0	3	0
5	33	Ren et al (2019)	1	0	3	1	4	10	4	7	3	0
6	26	Kairies-Alvarado et al (2021)	3	0	7	0	4	5	0	5	1	1*
7	22	Amos et al (2019)	0	0	0	1	0	7	10	0	4	0
8	20	Matarneh et al (2019)	1	0	2	0	0	1	8	2	6	0
9	14	Atkin and Bildsten (2017)	0	0	0	0	0	0	12	0	2	0
10	13	Bortolini and Forcada (2020)	1	0	2	1	1	1	3	0	4	0
11	12	Støre-Valen and Buser (2019)	1	0	0	1	1	0	7	0	2	0
12	12	Lyhne et al (2012)	1	0	0	0	4	3	3	0	0	1**
13	11	Vukmirovic et al (2021)	0	0	0	0	0	7	1	0	3	0
14	11	Truong et al (2018)	1	0	1	3	0	5	0	0	1	0
15	10	Dahanayake and Sumanaratna (2022)	0	0	0	0	0	6	0	0	4	0
16	10	Rafudeen (2020)	0	0	1	6	1	1	0	0	1	0
17	8	Amponsah-Tawiah et al (2016)	1	0	1	4	0	1	0	0	1	0
18	6	Kristl et al (2020)	0	0	0	1	1	3	0	0	0	1
19	5	Bröchner et al (2019)	0	0	0	1	0	4	0	0	0	0
20	4	Raendran et al (2020)	0	0	0	2	0	1	0	0	1	0
21	4	Nijkamp and Mobach (2020)	0	0	0	2	0	1	0	0	1	0
22	4	Ehrenberg (2021)	0	0	3	0	0	0	0	1	0	0
23	2	Kumar et al (2016)	1	0	0	0	0	0	1	0	0	0
24	2	Maryono et al (2016)	1	0	0	0	1	0	0	0	0	0
25	2	Krabbe (2019)	0	0	1	0	0	0	0	1	0	0
26	1	Jansz et al (2021)	0	0	0	0	1	0	0	0	0	0
27	1	Neurath et al (2012)	1	0	0	0	0	0	0	0	0	0
Total	449		22	2	37	80	24	74	94	33	53	30

* The 17 counts of standards in the top 1st article comes from the journal name and in the articles own title. The 1 count of standards in the 6th article relate to a mentioning in the title of the article.

**The 1 count of standards in the 12th article appears in " Summary Points" which appears after the conclusion.

Table 5. Sections where the articles referred to 'standards'

The following sections briefly present the 27 journal articles in thematic groups based on the role that standards played in the research. The sections discuss the use of the term 'standard' and present the main topics that emerged from the analysis, such as ambitions for the co-development of research and standards, digital transformation efforts and particularly, the use of BIM, sustainable transformation efforts (e.g., transitioning strategies), FM processes and practices and standard and knowledge production within practice and academia.

3.1 Ambitions for the co-development of research and standards

Several research articles focused on the relationship between standards and the research result, i.e. the output of the research was promoted as potential for future standards. The analysis found examples in which one or more standards were used to frame the research scope and purpose. The following paragraphs summarise three examples of co-development between research and standards.

Toledo et al. (2014) assessed several standards, including gaps and needs, and developed and proposed a new standard for standardisation organisations to adopt. Toledo et al. (2014) discussed intelligent transportation systems and focused on a particular protocol named NeMHIP that they developed and proposed as a suitable method for standardisation. The authors stated, 'All of these features make NeMHIP a feasible and worthy solution for being considered by the standardization organizations' (p. 478). Toledo et al.'s work contributes to the digital research and standardisation stream because it is centred on the transmission and security of information and electronic signals sent vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I). Toledo et al. were less occupied with how people and organisations use vehicles.

Top	#	Authors	Main topic	Research and standardisation stream	Examples of standards mentioned in article, ways of referring to the term "standard" including
1	83	Toledo et al (2014)	Intelligent Transportation Systems (ITS)	Digital	ETSI TR 102 638, ETSI TR 102 731, ETSI TR 102 791, ETSI TR 102 893, ISO 21210, SO/TR 11766, ISO/TS 17574, ISO/TS 17444-1
2	60	Bieser et al (2020)	FM in data centres	Management-Technical	ISO 15686-1, DIN 32736, 2000 GEFMA 100-1, GEFMA 100-2, ISO 41001, ISO 41011, ISO 41012, ISO 41013, ISO 31000, VDI 6009, EN 50600, EN 15978, EPA 1993, EN 15221 and the EN 50600 structure
3	39	Jang and Collinge (2020)	BIM-FM asset management	Digital	ISO 19650-1, ISO 19650-2, PAS 1192-1/2
4	34	Dzulkifli et al (2021)	Building maintenance	Management	BS 3811, ISO 9001, ISO 14001, ISO 50001 and ISO 55001, ISO 41001, BS 3811
5	33	Ren et al (2019)	Building life cycle management	Digital	ISO 16739, ISO 16739-21, New Rule of measurements (NRM), Civil Engineering Standard Method of Measurement (CESMM4), Method of Measurement for Highway Works (MMHW) and Building maintenance price book (BICS), and expressions as standardized models for information, inventory, requirements, measurements, and workflows
6	26	Kairies-Alvarado et al (2021)	Energy efficiency	Technical	UNE-EN 15978, ISO 14040 and expressions as standardized methods, protocols, and ways of measuring, energy efficiency policies and standards, and standardized use of buildings
7	22	Amos et al (2019)	FM performance measurement	Management	BS EN 15221-7, ISO 41001, standards as tools
8	20	Maraneh et al (2019)	BIM for FM interoperability	Digital	Expressions as information exchange standard, BIM open standard and IFC open standard
9	14	Adkin and Bildsten (2017)	Editorial - Future of FM	Management	ISO 41001, ISO 50001, ISO 9001, ISO 14001, BS 8536-2, BS 1192 and PAS 1192
10	13	Bortolini and Forcada (2020)	Text mining in building maintenance	Management-Digital	EN 15232-1 and ISO 41001
11	12	Støre-Valen and Buser (2019)	Sustainable FM	Management	ISO 41001, ISO41011, ISO41012, BREAM, and regulations as Directive 2012/27/EU, BfS2013, TEK17
12	12	Lyhne et al (2012)	Safe and efficient use of ICT	NA	Expressions as standard protocol and standard set of questions
13	11	Vukmirovic et al (2021)	Extreme indoor air pollution	Technical	ISO/FIDIS 41001, The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62-1989
14	11	Truong et al (2018)	Tourist satisfaction		Standardised processed and methods, i.e. standard deviation
15	10	Dahanayake and Sumanarathna (2022)	Integrating IOT-BIM based smart FM	Digital	ISO 41001, ISO 50001, and expressions as standard designs and building codes, standard procedures, FM-related standards, standard data management and standard classifications
16	10	Rafiqdeen (2020)	FM in oil and gas sector	Management	ISO 41001
17	8	Amponsah-Tawiah et al (2016)	Occupational Health and Safety Management	NA	standardized questionnaires, standardized root mean square, and standard error
18	6	Kristl et al (2020)	Refurbishment of heritage buildings	Management	ISO 41001 and several other building regulations and codes, expressions describing research method and common ways of practice, i.e. standards were one document type search for in the literature
19	5	Bröchner et al (2019)	Editorial - Future of FM	NA	BREEAM in USE international standard for commercial buildings, LEED, ISO 41001
20	4	Raendran et al (2020)	IOT in FM - Smart toilets	Digital	ISO 41001
21	4	Nijkamp and Mobaach (2020)	Urban FM	Management	ISO/FIDIS 41001, European Committee for Standardization (used twice as a reference for EN 15221-1)
22	4	Ehrenberg (2021)	Trend in FM - ESG, FM and digital tech	Management	ISO 41001
23	2	Kumar et al (2016)	Medical stores management	NA	Standardised document protocols
24	2	Maryono et al (2016)	Energy resilience assessment	NA	Standardisation of provisions
25	2	Krabbe (2019)	Implementing global strategic FM	Management	ISO 41001
26	1	Jansz et al (2021)	FM in Unis - Campus interactions	NA	Standardised interview protocol
27	1	Neurath et al (2012)	Implementation of contingency plans	NA	Standardised plan for guidance

Table 6. Articles' main topic, way of referring to standards and appropriate research and standardisation stream

Standards and norms were central to Beiser et al.'s (2020) work, which focused on assessing FM in data centres. They were among the researchers who indirectly called for research to ensure standardisation, and they discussed and analysed several standards. Beiser et al. (2020) emphasised the need for further research to develop suitable frameworks, as 'there is no uniformity with regard to the implementation of standards, methods, and certifications' (p. 232). The purpose of Beiser et al.'s research was to identify any risk management solutions. Beiser et al. (2020) presented two different ways of referring to standards. They used the term to refer to standardisation bodies but also used specific standards to describe what FM is and what it includes. Beiser et al.'s work is an example of a management stream that intersects with a technical stream, as they emphasised how things work in practice and simultaneously researched 'building codes' for data centres with the EN50600 series. Beiser et al. explained that 'the most common cause of problems lies in processes and practice, rather than architecture or equipment' (Beiser et al., 2020, p. 229).

Krabbe (2019) provided a practitioner's perspective on the implementation of strategic FM on a global scale, contributing to the management stream by showing how standards influence FM practices. Use of the term 'standard' was limited in Krabbe's article, but it was thoroughly applied and showed the connection among article production, practice improvement and the benefits of standardisation. In implementing strategic FM, the Bayer firm relied on ISO 41001 to guide its journey of transforming its 150-year-old structure to a modern, strategic FM function. With a portfolio of 1,500 sites and 9,500,000 square meters, the corporate real estate department's transformation took three years, from 2016–2018. The first year of the process was dedicated to 'setting up a proper project team' (Krabbe, 2019, p.357), which included internal experts and an external expert who were knowledgeable about the ISO 41001 process. Because the involvement of the management board was uncertain and the project risked being terminated if its value was not proven, the project structure was essential for success. This phase included obtaining an overview of the footprint of FM (both in-house and outsourced), the cost for real estate, the global key performance indicators and an idea of the potential collaboration structure between global and local functions. After the initial phase was complete and the board approved the project, the next six months were used to define the FM processes and responsibilities in detail for all office buildings. The same activity was conducted for the remaining facilities during the following seven months. The final phase of the project involved implementing the new practice and proving 'that a common strategic approach in FM would bring success' (Krabbe, 2019, p. 362). ISO 41001 was published in 2018, so Krabbe was one of the first researchers to study the effects of applying ISO 41001, and he proved the benefits that standardisation experts bring to knowledge acquisition and exploitation.

3.2 Standards and digital transformation of the built environment

Several articles focused on BIM and FM, as this discipline greatly depends on standardised terms and approaches to facilitate application and tool development. As the following discussion indicates, many of these articles can be categorised under this topic related to digital transformation and the previous topic regarding co-development.

Jang and Collinge's (2020) work contributes to the digital stream because they focused on topics such as 'deficiencies in BIM regulations and standards, inaccurate information exchanges, software interoperability issues and unclear requirement definitions' (p. 1). The article reviewed critical issues regarding FM and asset management integration and used the term 'standard' to refer to globally recognised standards and BIM regulations.

Dzulkifli et al. (2019) represent the management stream. The researchers focused on issues with building maintenance and recommended best practices. They discussed the use of digital technology

such as Computerized Maintenance Management System (CMMS), BIM, augmented reality, virtual reality and Information and Communications Technology (ICT) systems and the ways that these tools support decision-making, including necessary skills to use such technologies. Dzulkipli et al. (2019) were one of the few researchers who referred to the ISO 41001 standard as a keyword. They used this standard to frame their research question and study. Dzulkipli et al. referred to additional standards in their article, some of which were used to define terms. They concluded that additional studies using ISO 41001 as a framework would help the maintenance practice become more efficient. Thus, this study is an example of co-development, as was the case with Matarneh et al. (2019).

Matarneh et al. (2019) focused on identifying future directions for research by investigating the relationship between BIM and FM. Their discussion focused on the disadvantages that the lack of interoperability between BIM and FM systems caused for facility managers, thus representing the digital stream. Interoperability is closely related to digital transformation and information transmission. Matarneh et al. centred their discussion on open standards for IFC and BIM. To resolve these issues, they called for collaboration between practice and academia. Matarneh et al. most frequently used the term ‘standard’ in expressions such as ‘information exchange standard’ or as ‘standardized practical processes to integrate different information sources . . . to provide a rich semantic database to support FM systems’ (Matarneh et al., 2019, p. 9).

Atkin and Bildsten (2017) represent the management stream. Their article provided an editorial discussion of the future of FM using six main topics. In relation to innovative technology, Atkin and Bildsten discussed product data exchange and BIM and explained that the focus on these technologies had prevented the exploration of other opportunities to use technology (e.g., AI) and had created unrealistic expectations for facility managers and other individuals. In the section on regulations, Atkin and Bildsten (2017) mentioned seven different standards and explained that ‘the extent to which standards have been defined for its work’ (p. 120) is a sign of maturity in the sector.

Bortolini and Forcada (2020) addressed text mining in building maintenance, but they did not mention a predominant standard. They referred to standards as tools that help facility managers and other individuals. Based on the use of text mining, Bortolini and Forcada’s work may be considered part of the digital stream, but their use of this method also relates to the management stream. Bortolini and Forcada focused on maintenance practice and how non-standardised information in software systems can be extracted and used for practice. Therefore, they extracted end-user requests from a software system and used text mining to identify the most common problems related to operation and management. Using this type of systematic text mining approach can be part of a future digital solution. If Bortolini and Forcada aimed to develop an algorithm to improve a software system or information transmission between systems, the article falls within the digital stream. Even though they developed a text mining approach, their aim was not to improve the system but to understand the content of the information and enable facility managers to analyse non-standardised information outside a software system, indirectly indicating a desired functionality for this type of software. Thus, Bortolini and Forcada’s contribution borders the digital and management streams.

Dahanayake and Sumanarathna’s (2022) work relates to the digital stream, as they explored opportunities for the integration of IOT with BIM. They were interested in the transmission of information from one system to another. They predominantly mentioned the term ‘standard’ in their results section. Dahanayake and Sumanarathna (2022) referred to several specific standards relating to FM, used terms such as ‘standard classifications’, and explained that digitalisation is needed to meet the requirements for FM standards.

Raendran et al.'s (2020) research on smart toilets falls within the digital stream, as the authors were interested in the user-to-user transmission of information (sent from a sensor via a cloud to an app) that showed whether a toilet was occupied, rather than in the actual use of the toilet. Raendran et al. (2020) commented on the progress of FM standardisation and the need to meet ISO certification requirements for FM to advance the application of digital technologies for IoT and AI related to smart toilets.

Ehrenberg (2021) was unique in that she simultaneously focused on digital transformation, ESG and sustainability and explained that digital transformation is a key enabler 'to realise the potential of the managing agent—the strategic adviser role envisioned 20 years ago' (Ehrenberg, 2021, p. 213). Even though the article discussed digital aspects, Ehrenberg's work relates to the management stream, as her goal was to analyse trends and their influence on outsourcing practices in corporate real estate. Ehrenberg (2021) highlighted the years long efforts of FM leaders and educators to develop a globally accepted definition for FM, as expressed in ISO 41001, and she explained that 42 countries were involved in the development process.

3.3 Standards and sustainable transition in the built environment

Several articles focused on society's transition towards a sustainable future, particularly the transition of strategies, processes and practices related to FM. The authors of these articles considered standards to be potentially powerful tools for enhancing the awareness and implementation of best practices. A few authors also highlighted some weaknesses. For example, the standards are still too unknown to have a significant impact, and that standards risk becoming an implementation target of their own.

Kairies-Alvarado et al. (2021) conducted a study related to 'the application of energy efficiency standards' (p.1) and referred to standards as tools and standardized processes for reducing the carbon footprint. The authors' interest in the impact of using construction materials on the carbon footprint indicates that their article relates to the technical stream.

Støre-Valen and Buser (2019) focused on how FM practices can improve sustainability efforts. Therefore, their work relates to the management stream. The authors mentioned national and regional regulations and specific standards relevant to FM and explained that practitioners are unaware of them and their potential to facilitate sustainable transformation.

Vukmirovic et al.'s (2021) article '[dealt] with a phase of the construction process that is a cause of extreme indoor air pollution in newly built facilities'. Thus, this research is close to the technical stream. Arguably, the research relates to a construction management stream, since it focused on construction management practices and the benefits of involving facility managers during the construction process. The authors mentioned specific standards and identified several FM activities that help prevent indoor air pollution, including the FM activity of 'new construction/reconstruction and construction management, applying the building codes/standards and FM's role as "facilitator" within the construction phase' (p. 5).

Kristl et al. (2020) used a literature review to examine indicators of sustainability and universal designs for the refurbishment of heritage buildings. The authors aimed to contribute to refurbishment practices, so their article falls within the management stream. They included standards (as documents) in their literature review and used the 'term' standard to describe common ways of practice. For example, Kristl et al. (2020) explained that researchers have determined that the 'energy retrofitting of heritage buildings to current standards is essential for improving

sustainability’ (p. 603). The term ‘standard’ was used in the results section to describe needed service levels and to emphasise students’ use of standards during their education.

Bröchner et al.’s (2019) contribution does not necessarily relate to any of the three research and standardisation streams (i.e., digital, management or technical streams). Bröchner et al. (2019) presented an editorial that focused on how research analysis contributes to opportunities for FM research. The authors focused on the influence of megatrends, such as digitalisation and sustainability, on research. They identified eight categories of sustainable FM. One of these categories was sustainability tools and standards, and mentioned a few standards (Table 6).

3.4 Standards and academic knowledge production

The authors of these aforementioned articles used standards for definitions and provided a methodological declaration of their research processes. These articles also provided examples of the increased application of standards in academic work. Most of the contributions to the theme of knowledge production relate to the management stream.

Ren et al.’s (2019) research represents the digital stream. This research examined building life-cycle management and focused on an information exchange scheme in which ‘performance measurement in VFM [value for money] still lacks automation and information exchange schema’ (p. 1). The authors developed a schema that solved this issue. Ren et al. (2019) concluded that to facilitate the standardisation of contracts and data reliability, BIM-based life-cycle management is required.

Nijkamp and Moback (2020) aimed to contribute to urban FM practices, so their research relates to the management stream. References to ‘standards’ related to standardisation bodies or standards relevant to FM, which were used to define FM in the theory section.

Amos et al. (2019) focused on performance measurement and how to facilitate it through the use of BIM and advanced automation. The authors’ aim was to identify research gaps, provide guidance for future research and determine how future studies can improve FM practice. Consequently, Amos et al.’s (2019) article falls within the management stream. Their article can also be used to indicate potential needs for standardisation and works well as an introduction for the current ISO/TC 267 working group, which is currently developing an FM performance standard. Thus, this article exemplifies how research can inform standardisation efforts. Amos et al.’s (2019) work focused less on the transmission of information and presented standards as tools for successful benchmarking. This was strengthened in the discussion section, which mentioned specific standards. In addition, Amos et al. (2019) called for the increased use of standards in academic research, explaining that ‘the application of these standards in academic research is limited. This gives an indication that the blend between academic theory and practice is not strong in FM PM [performance measurement]’ (Amos et al., 2019, p. 500).

Rafiudeen (2020) argued that few studies exist of the oil and gas sector and assessed the service quality gap in related FM services, including customer satisfaction. The author’s aim was to improve practices, so this article relates to the management stream. The meaning of the term ‘standards’ varied in Rafiudeen’s (2020) work. It was mostly defined as a formal standard document, an internal procedure, or a quality level. Rafiudeen mentioned only one specific standard for FM, which they also used as a key word, and referred generally to standards as a positive contribution to FM. Other uses of the term ‘standard’ included ‘setting standards’ and ‘corporate standards’.

3.5 Standards as a general term

The articles in this category on standards as a general term are beyond this article's original scope of understanding the role that standards, which are the formal documents created by standardisation organisations, play in research. These articles illustrate how the term 'standard' appeared in the obtained results from the SLR method. This work demonstrates that the proper definition of a term is required to understand what it actually refers to and whether it relates to mathematical equations or other elements of the research.

Lyhne et al. (2012) focused on the safe and efficient use of ICT and used 'standard' to refer to processes. They used phrases such as 'the lack of standardisation' or 'semi-structured interviews and focus groups were conducted using a standard set of questions' (p. 454). Kumar et al. (2016) used the term 'standard' to refer to processes as in 'standardized documentation protocols' (p. 65). Maryono et al. (2016), Jansz et al. (2021), Neurath et al. (2012), Truong et al. (2018) and Amponsah-Tawiah et al. (2016) made similar references, such as 'standardisation of the provision', 'standardised interview protocol', 'standardised plan for guidance', 'standard deviation', 'standardised questionnaires', 'standardised root mean square' and 'standard error'.

4. Discussion

This article aimed to identify the role of standards in research and to substantiate the relationship between standards and research in the context of FM. A systematic literature review was identified as the best approach, particularly since FM standards at the ISO level are relatively new (since 2017). It was encouraging to find a considerable amount of literature, with 198 articles on both FM and ISO. It was also encouraging to find that the ISO 41001:2018 standard was a common reference in many of the articles.

The results show that FM practitioners, researchers and standardisation experts must join forces to accelerate the advancement of FM. Due to the key role of FM in planning, managing and optimising buildings and other facilities throughout their lifetime, the advancements in FM regarding sustainability, resilience and digitalisation will with great certainty accelerate the societal transition of the built environment.

Several articles called for greater collaboration between practice–research and research–standardisation. Standardisation bodies frequently call for experts to participate in developing and updating standards. Focusing on joint efforts is a practical tool to initiate collaboration that can produce effective ways to make the world a better place; i.e., digital technologies are key enablers for sustainable and digital transformation, and standardisation is an important tool for the twin transition that combines digital and green efforts.

There is both an opportunity and a need for theory development related to the interrelation between the development of standards and research. This article calls for studies developing new knowledge, theories, frameworks, and models around the relationships between research and standards, such as the ISO 41000-series for FM. This article's analysis revealed that researchers use standards to frame their research, primarily in the discussion, theory or results sections of their articles. At times, standards are merely used to define a term, but other times, standards create the background of the research and shape research approaches, e.g., Toledo et al. (2014), Dzulkifli et al. (2019), Bieser et al. (2020) and Jang and Collinge (2020). Thus, by illustrating the various ways in which research enhances standards and standards influence research, this article provides examples for inspiration and promotes stronger relationships between people and processes in research and standardisation.

Some articles illustrated the value of research on the development of standards and vice versa. The best example is Toledo et al. (2014). These authors deliberately evaluated standards and their gaps and developed and proposed a new approach for standardisation bodies to adopt. Other examples include research that provided new standards or that called for greater integration of research and standardisation. For example, Amos et al.'s (2019) research on performance works equally well for standardisation experts and FM researchers. Regarding the research method, both Toledo et al. (2014) and Dzulkipli et al. (2019) are examples of using standards to design the entire research approach, especially Toledo et al. (2014), since they developed a protocol and suggested it as a much-needed standard.

This article explains that the role of standards in research can be examined using the following types of analyses:

- Thematic analysis of the researcher's primary interest (i.e., subsections of Chapter 3);
- Categorical analysis of the standardisation and research streams (i.e., Table 6);
- Textual analysis of the use of standards in the text and the author's intention in using the term 'standard' and whether it relates to formal documents, organisations' internal practices, mathematical equations or other elements of the research (i.e., Table 5);
- Methodological analysis of the influence of standards on research methods or
- Directional analysis of the author's interest in contributing to a certain community and whether his or her primary interest is to enhance research, practices or standardisation.

Based on personal experience as researchers and standardisation experts, the authors of this article know that research inspires standards, and standards and research can be intertwined at times, as the development of standards includes extensive market research and academic literature. Thus, the authors of this article expect that research and standardisation will be more intertwined than explained in this article.

Improving and implementing international FM standards is an important driver of accelerating the transition of the AEC/FM industry to a digital and sustainable world. Standardisation bodies and research organisations, such as the CIB, are important facilitators of this societal transformation and contribute to society's demand for sustainability and resilience.

5. Conclusion

The purpose of this article is to investigate the role of standards in current research and the relationship between standards and research, particularly FM research that explains various ways in which researchers, research organisations and standardisation bodies can collaborate for the sustainable and digital transformation of the built environment.

The systematic literature study identified 27 core articles relevant to FM and ISO standards. The ISO 41001 Facilities Management Standard was a common reference in the literature, but it also referred to other standards. The literature study enabled the development of a framework researchers can use to analyse the role of standards and their relationship with research.

This study found that researchers focus on standards, and some even suggest that their research contributes to future standards. This supports the need for the relationship between the research community and standardisation bodies to be strengthened for the benefit of the FM discipline.

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