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Research and Evidence-based standards: Research and standards in combined efforts for a sustainable transformation of the built environment

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Abstract. Standards for products, processes and management systems are important tools for the much-needed sustainable transformation of the built environment. With standards, we refer to documents coming from standardisation bodies such as ASTM/ANSI (USA), BSI (UK), CEN (Europe), and ISO (global). The purpose is to investigate the role standards play in current research to exemplify various ways CIB and standardisation bodies can combine efforts for a sustainable transformation of the built environment (BE). Scientific journal articles were identified through literature review. The paper focuses on the building's use and operation phase and especially the new Facility Management (FM) standards (ISO 41000 series) developed by the technical committee ISO/TC267. Our findings are based on a closer analysis of 10 journal articles from 2010-2021 after identifying 198 relevant articles. The articles refer to a broad range of standards which proves the relevance of standards in building research. There are no proves of how research has influenced standards, only examples of research aiming to enhance standards. Improving and implementing international FM standards is a driver to improve the BE sustainability. CIB and the standardisation bodies have an important role to accelerate the societal transition processes and contributing to society's demands of sustainability and resilience.

1. Introduction

Sustainable transformation is a great need for the globe to ensure the longevity of mankind. Many efforts are on the rise. As an example, Europe aims to be the world's first climate-neutral continent by 2050 and has started to ask questions as "How can science guide effective action"? [1, 2]. And lately, the UK and the USA also joined this quest [3]. Another example is ISO's efforts to map and categorize all their standards according to the sustainable development goals (SDGs) to visualize and guide users on what standards support which goals and as such "help them to rise to the challenge" [4]. The SDGs, which are part of the UN 2030 agenda launched by the United Nation in 2015,



“represent an urgent call for action by all countries – developed and developing – in a global partnership” [5] to transform our world into a sustainable one.

Facility management (FM) plays a key role in the global transition to a sustainable, climate-neutral world. As an example of the close relation, we can draw attention to some of the key parts in the definitions of both FM and sustainability – both definitions consider a wider scope taking the economy, the environment, and also social aspects into consideration. Sustainability, as defined by EN 17485:2021 [6], concerns the “state of the global system, including environmental, social and economic aspects, in which the need of the present are met without compromising the ability of future generations to meet their own needs”. The definition of FM, as defined by ISO 41011:2017 [7], is an “organizational function which integrates people, place and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business”.

The key role that FM discipline plays in our society was further underlined during the COVID-19 pandemic when the coronavirus ruled all the corners of the world during year 2019 - 2022. This period is also commonly referred to as the corona period and the corona pandemic. During the corona pandemic, the role of Facility Managers was recognized for their important contribution in providing spaces, infrastructure, and services to people and the organizations, to help all professionals acting in the frontline. As an example of this, and as a consequence of the Covid 19 pandemic, Norwegian cleaners were included in the Norwegian government’s list of critical societal functions [8]. Solutions were initiated and created all over the world, including standards and technical reports such as ISO/PAS 45.005:2020 Occupational health and safety management – General guidelines for safe working during the COVID-19 pandemic and ISO/WD TR 5202 Buildings and civil engineering works — Building resilience strategies related to public health emergencies — Compilation of relevant information.

1.1. Development of standards

The development and adoption of standards can be a slow process, particularly on a global scale. However, when the implementation is complete, it enables smooth collaborations. An everyday example that most people can relate to is our use of payment cards and ATM machines. Most of us regard this as a rather smooth and obvious process. It might seem obvious that every payment card in the world fits every ATM-machine, however it is standards that ensures these fit around the globe, e.g., ISO/IEC 7812-1:2017 and ISO 8583. Another example is the implementation of the metric system.

Standardisation bodies and the aim of easing productivity, collaboration and innovation has a long history. The French revolution was important for both Europe, and the world, with regards to standardization, as it facilitated the establishment of the metric system - a unified system for weights and measures [9]. However, it might be a long process before a new standard is implemented and demonstrate its potential, which the case of the metric system also illustrate. The use of the metric system started in France in 1801 and became obligatory in 1837. The United Kingdom did not adopt the system before 1965 [10]. Whereas the USA was quicker in its adoption, as the USA legalised the metric system already in 1866, enabling non-compulsory use of it. After a while, standardizations bodies emerged around the world (see Table 1). Today, most countries and continents have a standardization body. Some continents, as Europe has several. In total, Europe has three standardization bodies [9].

1.2. Purpose and research questions

The purpose of this paper is to investigate the role standards play in current research and in particular in building research to exemplify various ways CIB (International Council for Research and Innovation in Building and Construction) and standardisation bodies can combine efforts for a sustainable transformation of the built environment. The research questions is: *What role do standards play in the reviewed journal articles and what are the standards' relation to research?*

Table 1. Examples of standardization bodies around the globe

Location	Standardizations body	Founded year	Reference
USA	ASTM – American Society of the International Association for testing and material (founded by Pennsylvania Railroad engineers and scientists)	1898	ASTM Internationals [11]
UK	BSI – <i>British Standards Institution</i> The world’s first National standardizations body according to BSI	1901	BSI (not dated) [12]
USA	ANSI – American National Standards Institute	1918	ANSI [13]
Brazil	ABNT - Brazilian Technical Standards Association	1940	ISO (2021b) [14]
Norway	SN – <i>Standards Norway</i> / NS – Norsk standard (previously, Norges Standardiseringsforbund)	1923	Standard Norge – Wikipedia [15]
Global	ISO - International Organization for Standardization	1946	ISO - The ISO Story [16]
Europe	CEN – The Comité Européen de Normalisation	1961	Wenzlhuemer 2010 [9]
Europe	CENELEC – The Comité Européen de Normalisation Électrotechnique	1973	Wenzlhuemer 2010 [9]
Europe	ETSI – The European Telecommunications Standards Institute	1988	Wenzlhuemer 2010 [9]; Toledo, 2014 [17]

Standards can be understood in many different ways, e.g. as product standards (e.g. for electronic products such as fridges and electric points), process standards (e.g., welding processes; measurements and climate accounting) and management systems standards (MSS).

The scope of this paper is MSS’s of relevance for facility management (FM), i.e. product and process standards are out of the scope of this paper. Examples of relevant MSS standards are such as [18]: “ISO 9001: Quality Management System Standard, ISO 14001: Environmental Management System Standard, ISO 50001: Energy Management System Standard, ISO 55001: Asset Management System Standard, ISO45001 Occupational Health & Safety management system, ISO 31000 Risk Management and ISO 41001 Facility management – Management systems – Requirements with guidance for use”.

2. Research methodology

Our literature review is inspired by Nielsen et al [19] who divided their systematic literature review into the following steps:

- 1) Purpose of the literature review identified and agreed upon
- 2) Protocol and training of the researchers ensuring mutual understanding
- 3) Agreeing on the journals, databases, and key words to be use
- 4) First screening round (titles and keywords)
- 5) Second screening round (abstracts)
- 6) Data extraction and analysis

The purpose (step 1) of our literature review was to identify and exemplify different ways that research has influenced and enhanced standards both in the past and in the future, yet also to develop a framework proposing how researchers in CIB and ISO can benefit from collaborating. Following this, all authors agreed that the focus should be on buildings use and operation.

The process (step 2) for our literature review (protocol and training) was discussed in several meetings to refine the search process and analysis. After various pilot searches we decided to limit the searches to Science direct and Google Scholar and the following selection criteria’s (step 3):

- a) categories: *Research articles and Review articles*

b) timeframe: 2010-2021

c) limitation to only search on for keywords in the publication's sections for:

Title, abstracts, and author-specified keywords

d) Keywords used in search string 1, resulted in 100 publications:

standardization AND facility management OR facilities management or FM AND ISO

e) Keywords used in search string 2, resulted in 98 publications:

standardization AND facility management OR facilities management or FM AND ISO41000

The search identified 198 research papers referring to standardization and FM. For keywords and terms used to identify these 198 research papers, see point d-e above regarding protocol and training.

During the *first screening round*, the selected publications from each search were examined by their titles and journals to identify literature of relevance for CIB W070 (Facilities Management) and ISO/TC267 (Facilities Management). In this round, we identified to what extent the articles were eligible for further analysis through a traffic light colour scheme of green, yellow and red (see Table 2). Through this process, the green papers were identified as relevant for the next round of screening. This first screening reduced the number of publications from 198 to 48 green papers.

Table 2. Example of categorization during the first screening round

Article	Status	Reason for status
Vander Wal B and Kyle CL (2015) Decreasing Newborn Readmission for Hyperbilirubinemia, Journal of Obsteric, Gynecologic & Neonatal Nursing, June 2015	RED	Medical, no facility, facility services or standard focus
Renaud et al (2017) Calf management risk factors on dairy farms associated with male calf mortality on veal farms, Journal of Dairy Science	RED	Focus on animal health, no facility, facility services or standard focus
Gysel N, Welch WA Karavalakis G (2017), Particulate matter emission and gaseous air toxic pollutants from commercial meat cooking operations, Journal of Environmental Science	YELLOW	About food and maybe sustain-ability, cooking meat vs emissions, no facility or standard focus
Doherty et al (2017) Design and implementation of a performance assessment methodology cognisant of data accuracy for Irish wastewater treatment plants_2017_Journal-of-Cleaner Production	GREEN	About facility or facility services (wastewater plant)
Kevin et al (2021), Diuretic Renal Scintigraphy: The State of Practice and a Potential Opportunity for Standardization, Journal of the American College of Radiology.	GREEN	About standardisation

During the *second screening round*, the green articles were selected for further categorization. Still, the focus was on analysing their content by examining their titles and journals. In a few incidences where the title did not revile enough info to categorize the article, we studied the abstract to settle appropriate categorization according to building type, scientific domain and professional discipline. Through this process, we identified 27 out of the 48 articles that were eligible for the next step in our literature research. These 27 articles were assigned to the discipline categories "FM (facility management)" and "Management and Standardisation", see *Table 3*. The second screening round also categorized the articles according to a third category that aimed to identify the focus of the article, as illustrated in *Table 4*.

During the *third screening round*, the selected 27 articles were reduced to 25 articles, as we did not have full access to two of the articles. These 25 articles were scanned for the number of times that the term "standard" appeared within the article. In addition, a brief comment was made regarding the

articles' use of standards. For the purpose of this conference paper, it was decided to continue with a full read of the top 10 articles, that is, those articles mentioning "standard" most frequently. Through this third screening round, we reduced the number of publications from a total of 27 to 10 papers.

Table 3. Categorization of the 48 journal articles in the second screening round

Building type	#	Scientific domain	#	Discipline	#
Unknown	25	Engineering & Architecture	34	<i>FM (facilities management)</i>	17
Health care facilities	9	Health & Patients safety	7	<i>Management & Standardization</i>	10
Industrial	7	Leadership & 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 4. Categorization of articles by topic during the 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

The fourth and final screening round included a full read of the top 10 articles. During the reading process, we looked for how the articles treated standards and where the articles referred to the term "standard". That is, whether the articles referred to standards in their keywords, abstract, introduction, method, results, or conclusion. Our hypothesis was that standards predominantly are mentioned as motivating factors and that it relates to the artifact under construction. As such, we anticipated that articles referring to standards in the introduction merely did so to define a term, whereas articles that focused on standards in method, result and/or conclusion section used standards as a key element in their analysis. Of these reasons, we looked for the following in the third and final screening round: *What role do standards play in the articles and the standards' relation to research?*

3. Findings and discussions

The results of the third screening round, as illustrated in Table 5, showed great variance in the number of times (#) the term standard was mentioned – all from one to 83 times. Whereas the results of the fourth screening round, as illustrated in Table 6, showed a great variance of when and where the top 10 articles mentioned standards within the publication itself.

Table 5. Top 10 articles ranked by the frequency (#) in the use of the term “standard”

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 Dzul kifli 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 Matarneh 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 Atkin and Bildsten (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 an maintenance strategy.

Table 6. Location where articles referred to standards

Top	#	Abs.	Keyw.	Intro	Theory	Method	Results	Disc	Concl.	Ref.	Apx.
1	83	4	1	10	17	0	13	1	11	9	17 ^a
2	60	1	0	1	0	3	In disc	39	4	2	10
3	39	3	1	2	17	3	3	3	2	5	0
4	34	1	0	3	23	0	2	2	0	3	0
5	33	1	0	3	1	4	10	4	7	3	0
6	26	3	0	7	0	4	5	0	5	1	1
7	22	0	0	0	1	0	7	10	0	4	0
8	20	1	0	2	0	0	1	8	2	6	0
9	14	0	0	0	0	0	0	12	0	2	0
10	13	1	0	2	1	1	1	3	0	4	0
Total	342	15	2	30	59	15	42	82	31	39	10

^a The 17 counts of standards in the top 1st article comes from the journal name and in the articles own title.

The top 1st article, which mentions the term standard eighty-three times, do so through-out the entire article. As commented below table 6, many of these mentions were due to the journal's name and the title of the paper. As such, the real count when removing these additional is sixty-six times, which still represents the highest count. This top 1st article discusses Intelligent Transportation Systems (ITS) and focused on the suitability of a particular protocol (NeMHIP) which they develop. When Toledo et al [17] use the term standard they tend to do so when mentioning standardization bodies, documents or requirements, e.g. referring to "security related standards" (pg. 446). They do refer to a few specific standards, particularly in the intro and theory section, identifying the gaps and needs to be solved by their protocol: ETSI TR 102 638, ETSI 102 731, ETSI TS 102 791, ETSI TR 102 893, ISO 21210, SO/TR 11766:2010, ISO/TS 17574:2009, ISO/TS 17444-1:2012. Toledo et al [17] end their conclusion by suggesting that standardization bodies should consider their protocol: "*All of these features make NeMHIP a feasible and worthy solution for being considered by the standardization organizations*" (pg. 478).

The top 2nd article mentions the term standard more or less throughout entire articles, including in their appendixes. Standards and norms are central to Bieser et al [20] who discusses and analyses many standards, e.g. ISO 15686-1:2011, DIN 32736, 2000 GEFMA 100-1, GEFMA 100-2, ISO 41001:2017, ISO 41011:2017, ISO 41012:2017, ISO 41013:2017, ISO 31000:2018 and VDI 6009:2002. In addition, they also analyse a series of European norms (EN), such as EN 50600:2016, EN 15978:2011, EPA 1993, EN 15221 and the EN 50600 structure. The purpose of Beisers et al. [20]'s research is to identify if there exist solutions for risk management "or what they might look like" (pg. 219). In Beiser et al [20]'s result and discussion section, the term standard is used to refer to standardization bodies, while the mention of specific standards is used to describe what FM is and includes. They stress that further research is needed to develop a suitable framework, as "there is no uniformity with regard to the implementation of standards, methods, and certifications" (pg. 232). As such, they indirectly call for research to ensure standardization.

The top 3rd article, which mentions the term standard thirty-nine times, do so throughout entire article, however predominantly in the theory chapter. The article aims to review critical issues surrounding FM and asset management integration and use the term standard to refer to globally recognized standards and BIM regulations. During this quest Jang and Collinge [21] mention three specific standards in their theory section: ISO 19650-1 and 2, plus PAS 1192-1/2. They conclude that

“there is a greater need for collaboration and more communication between key stakeholders at early project stages” (pg.11) as “certain characteristics of construction project management result in persisting problems that impact the BIM-FM asset management journey (pg.11)”. To our understanding, there is no reference to a need for collaboration between researchers and practitioners, as researchers are not mentioned as part of key stakeholders.

The top 4th article predominantly mentions the term standard in the theory section (called Maintenance terminology). It is worth noting, that even though this article by Dzulkifli et al [22] do not mention the term “standard” as a keyword, the article refer to a specific standard as one of their keywords – the ISO 41001. They use this standard to frame their research question and entire research study: “This standard has the potential to be a great tool in monitoring the quality of maintenance services but is not widely implemented [...] Therefore, this study intends to comprehensively review building maintenance issues, suggest recommendations to minimize the issues based on literature and ISO 41001 guidelines,.. (pg. 1)”. In the article itself, they also refer to yet further standards: BS 3811, ISO 9001, ISO 14001, ISO 50001 and ISO 55001. These remaining ISO standards are merely referred to as management standards relating to the ISO 41001, whereas BS 3811 is used to define maintenance as a term. They conclude that yet further case studies using ISO 41001 as a framework are needed: “case studies are required to investigate further the efficiency of maintenance practice based on guidelines provided by ISO 41001 using the PDCA cycle as continuous improvement tool (pg. 11).”

The top 5th article mentions the term standard more or less throughout the entire article. The term is used to describe standardized models for information, inventory, requirements, measurements, and workflows, without necessarily referring to particular standards. Ren et al. [23] do however also mention a few standards specifically in their theory section (called Background); ISO 16739 and ISO 16739-21, yet also 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). They conclude that for standardization of contracts and data reliability to be enabled, it is necessary with BIM-based life cycle management.

The top 6th article mentions the term standard in the intro, method, result, and conclusion section. In the intro section, *standards are referred to as tools and standardized processes* for reducing carbon footprint. In the method section, the term standard is referred to as standardized methods, protocols, and ways of measuring, while in the discussion and conclusion section the term is included when debating energy efficiency policies and standards, and standardized use of a building. Kairies-Alvarado et al. [24] do mention two standards specifically; UNE-EN 15978 (mentioned in the intro) and ISO 14040:2012 (in method section).

The top 7th article predominantly mention the term standards in their result and discussion section. In the result section, standards are presented as a *tool for successful benchmarking*. This emphasis is further strengthened in the discussions section, which also mention specific standards: BS EN 15221-7 and ISO 41001:2018. In connection to this, Amos et al. [25] call for increased use of standards in academic research pointing out 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” (pg. 500). Here, FM PM refers to FM performance measurement.

The top 8th article, which mentions the term standard nineteen times, does so predominantly in relation to *standardized processes* and when discussing open standards for IFC and BIM. Matarneh et al. [26] main discussion revolves around the disadvantages that the lack of interoperability causes facility managers. To resolve the issues, they *call for collaboration between practice and academia*.

The top 9th article predominantly mentions the term standard in their discussion. Atkin and Bildsten [27] represent an editorial, discussing the future of FM according to six main topics: 1) Current debates, 2) Current context, 3) Innovative technology, 4) Regulation, standards, and codes, 5) Human resources and the future workforce, and 6) Strategic questions. The term standard is mentioned once in relation to innovative technology and eleven times in relation to regulations, standards, and codes. In relation to innovative technology, when Atkin and Bildsten [27] discuss product data exchange and

BIM, they comment that the major focus on these technologies has prevented the exploration of all the other opportunities that technology can bring (like AI) and created unrealistic expectations among facility managers and the like. In the section on regulations, [27] mentions seven different standards; ISO 41001, ISO 55000, ISO 9001, ISO 14001, BS 8536-2:2016, BS 1192 and PAS 1192, and comments that “the extent to which standards have been defined for its work” (p.120) is a *sign of maturity* in a sector.

The top 10th article does predominantly not mention any specific standard. Only in two cases does Bortolini and Forcada [28] specific standards; these are EN 15232-1:2017 and ISO 41001:2018 which both are mentioned at the end of their discussion. In both occasions, the standards are referred to as *a tool helping facility managers* and others.

4. Conclusions and further research

The purpose of this paper was to investigate the role standards play in current research and in particular in building research to exemplify various ways CIB (International Council for Research and Innovation in Building and Construction) and standardisation bodies can combine efforts for a sustainable transformation of the built environment. The research provides examples for inspiration and stronger relations between research and standardisation. Our research question was: *What role do standards play in the reviewed journal articles and what are the standards' relation to research?*

Our results do show that researchers use standards to frame their research primary in the discussion, theory or result sections. Sometimes standards are merely used as a reference defining terms, the identified top 10 papers all use standards to create the background of their research and to shape their research approach, e.g. Dzulkipli et al. [22], Bieser et al [20] and Jang and Collinge [21]. Our results show little evidence that research has influenced standards in the past within the studied journals, but we find research intending to provide new standards and research calling for greater integration of research and standardization. However, based on our own experience, as both researchers and experts in standardization committees, we do know that standards are inspired by research and that standards and research at times can be quite intertwined as the development of standards includes extensive market research, also academic literature. As such, we know research and standardization are more intertwined than we have been able to identify in this paper. Lately, journals have also started to call for research on standards [29]. In this regard, Toledo et al [17] can be seen as a scholar example, as they suggest their protocol should become a much-needed standard.

Improving and implementing international standards for facility management (FM) is a driver to improve the sustainability of built environment. CIB and the standardisation bodies have an important role to accelerate the societal transition processes and contributing to society's demands of sustainability and resilience. This research provides examples for inspiration and stronger relations between people and processes in research and standardisation.

This paper provides examples of various ways building research aim to enhance standards. Concurrently, we know from own experience the standardisation bodies have a constant call for experts to take part in the development and updating of standards. A focus on joint efforts of CIB W070 and ISO/TC267 to work together could represent a practical mechanism to start collaboration in the field of FM to produce effective ways to make the world a better place.

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