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ADOPTION OF BIM-RELATED INTERNATIONAL STANDARDS ACROSS EUROPE

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Abstract

Various standards concerning the implementation of building information modelling (BIM) are available. This paper investigates the correlation between the adoption of international standards and BIM implementation by practitioners across Europe. At the core of the research is a questionnaire answered by industry experts from 21 countries. The questionnaire results show that BIM implementation does not correlate with the adoption of international BIM standards. The results combined with literature indicate the need for better strategies for the diffusion of the standards. The findings pinpoint the potential improvement for more effective use of international BIM standards.

Introduction

Digitalization of the architecture, engineering, construction, and operation (AECO) industry is slow, however it is continuous albeit unevenly spread (Bolpagni, 2022; Charef et al. 2019). To support construction digitalization, standards are developed at multiple levels: company, associations, national, supranational or international. These are complemented with various guidelines, templates or best practices. The BIM standards are not adopted equally, and affect the industry in different ways (Charef et al. 2019). In addition, it is not clear if and how the standards reach relevant end users. Thus, this research aims to investigate the acceptance and usage of international BIM-regulating standards among practitioners across Europe. The work provides an insight on the BIM standards adoption, so their reach and usage could be improved in the future, which can contribute to accelerate construction digitalization. The reference to "standard" in this text means "BIM standards" published by the European Committee for Standardization (CEN), especially the dedicated BIM group CEN/TC 442 (CEN-CENELEC, 2022).

BIM definitions alone are various (Hjelseth 2017, Bolpagni 2022). As a result, different understandings of BIM may lead to false perceptions of the actual adoption. Therefore, it is required to determine the activities which are considered as "BIM implementation" and align them with the acceptance and usage of standards. The implementation in this research revolves around BIM concepts used in practice, which are recommended or defined by the standards. It focuses on the modelling and exchange of information during project delivery.

BIM adoption is a broad topic which may be investigated through various models of adoption framework at different scales. Past work by Succar and Kassem (2015) focused on macro BIM adoption, meaning "large collections of organizational adopters operating within defined national borders" (Succar and Kassem 2015). In this paper, instead, the focus is on individual BIM implementation within the organization and the consideration of international standards. BIM capability is defined in Succar and Kassem (2015) as willful implementation of BIM tools, workflows and protocols, and achieved through object-based modelling, model-based collaboration, and network-based integration, including technology, process and policy topics. Correlation between the technologies and processes, and regulating policies is a research topic addressed in this paper. Regarding BIM capability, Akintola et al (2020) emphasize how BIM changes the workflows and work practices, however gradually and over time. Lee and Borrmann (2020) explain the people, process, and technology framework for BIM adoption. They include three research papers based on actual construction projects, describing actual BIM adoption from multiple perspectives and issues from people, process, and policy points of view. Although BIM adoption is complex and covers many topics, already standardized BIM concepts will be used herein for assessment of BIM implementation and capability.

The standards considered in this study are listed in the Standards Landscape Explorer (EC3 Modelling and Standards Committee, 2023; Bolpagni et al, 2022). Several works have previously explored the adoption of BIM, including relevant standards. Edirisinghe and London (2015) investigate global adoption of BIM, concluding that national initiatives positively impact BIM adoption. However, individual BIM technologies and forms of BIM adoptions are not investigated. Qin et al (2020) investigate BIM adoption in China, indicating the importance of policy for the adoption and concluding that government incentives are the main factor in the BIM adoption. However, single BIM concepts and standards are not individually addressed. Lee and Borrmann (2020) claim that research investigating strategic policies originating from a country or an individual is required to speed up the BIM adoption process.

This paper reports the first results of a broader research carried out within the European Council on Computing in Construction (EC3) Modelling & Standards committee

that will inform the establishment of points of attention that could help as an aid for further strategies for standardization adoption and thereby support the increase of digitalization. Research dealing with standards adoption and BIM implementation is explored to detail, to get an overview of existing problems and proposed solutions. This is presented in the next section. However, a vast number of standards connected to BIM has not been related to the actual implementation of BIM concepts. This research gap keeps standardization bodies and policy makers in the dark regarding the effectiveness of BIM standardization. This gap is addressed by questioning industry experts, mainly BIM users in European countries, to identify problems and best practices, and describe points of attention with the support of literature.

Background

The literature review on standards adoption and BIM implementation includes 16 relevant research papers, which are summarized here. The BIM standards in the review follow a wider concept which goes beyond the ones published by CEN TC 442 (CEN-CENELEC, 2022). The rest of our literature review is divided in two thematically related parts: analysis of standards, and BIM implementation and standards adoption on the macro level (as findings may also be important for other levels), and level of organizations.

Analysis of standards

Alreshidi et al (2017) investigate the role of standards in promoting BIM during design, listing the limitations of paper-based standards, as opposed to technical-data exchange standards, such as data schemas. They investigate the role of standards with experts in the field, with most of them agreeing that, while the standards promote collaboration and BIM adoption, they are only guidelines and do not necessarily improve collaboration in practice. Other issues at play regarding paper-based standards include: (a) difficult implementation within existing technological solutions, (b) lack of adoption by some end users, (c) lack of clarity around governance behind the standards, (d) their content reflects the needs of large companies and specific groups of stakeholders, and (e) constant change in the technology and standards landscape. A BIM governance framework is developed to speed up collaborative BIM with cloud technology. The research of Alreshidi et al (2017) describes how the standards are considered guidelines contrary to technical-data standards, and do not necessarily improve collaboration. Hjelseth (2017) concludes that the existing BIM standards, guidelines and research focuses on use of programs, and much less on the processes and people. In the same paper, the author notices that the presentations advertising BIM often focus on processes and people, unlike the reviewed standards, guidelines and research. Sacks et al (2016) do a qualitative review of a selection of 15 BIM standards and guides and investigate which elements of BIM adoption are described or prescribed within them. Out of ten selected topics, simulation and analysis, interoperability, BIM execution plan, and modes of collaboration are found to be most frequent, followed by the role of the BIM manager, and operation and maintenance requirements. However, they do a review of documents without investigating their actual use in practice. Daniotti et al (2020) focus on BIM technological aspects and information representation, considering industry foundation classes (IFC) standard (ISO, 2018), detecting technical challenges in the current data scope which would guarantee transparency, storage continuity and readability. They focus on the technical aspects of the standard and the implementation challenges.

Existing BIM standards are found to be insufficiently addressing certain domains, for instance the infrastructural projects as underlined by Hijazi et al (2017). Project specifications such as asset information model (AIM), exchange information requirements (EIR), or level of detail (now level of information need according to ISO 19650 series), in their current form are more suitable for building design, and need extensions for the specifics of infrastructure. Osello et al (2020) also tackle BIM adoption for infrastructure projects, based on the case study. With a real case they provide a new framework for development and management of data which is missing and is required due to the complexity of infrastructural projects involving several disciplines.

BIM implementation and standards adoption

- Macro level

Several research papers investigate BIM implementation in relation to the use of (inter)national standards. Antwi-Aftari et al (2018) posit that critical success factors for BIM implementation are not clearly defined. They perform a literature review and identify the five most relevant success factors: collaboration of stakeholders, earlier and accurate 3D visualization of design, coordination and planning of construction works, enhancing exchange of information and knowledge management, and improved site layout planning and safety. Aside from being a mixture or very broad and surprisingly specific factors, the authors do not provide means to measure these indicators. Charef et al (2019) have comparison between EU countries regarding BIM adoption and barriers to it. They show a discrepancy between countries, and indicate a need for action on the EU level so the latecomers to BIM implementation would reach the same level of adoption. Kassem and Succar (2017) compare macro BIM adoption across various countries based on their previous work (Succar and Kassem, 2015). They validate the macro BIM adoption models, and evaluate country-specific adoption, finally proposing a template for developing a national BIM roadmap. However, country-specific adoption results are now outdated due to the fast evolution of the topic. There are also country-specific investigations such as that of Robitaille et al (2021) who assess the adoption of the ISO 19650 standard series in Canada through a case study project. They recognize the obstacles in the adoption of the standards, suggesting they give too much room for interpretation. They also show that the standards are not properly understood and implemented in the practice. Hooper (2015) conducts a survey in Sweden which

investigates the BIM standardization efforts for different stakeholders in the construction industry. The results indicate that national standards are most appreciated, and that stakeholders have different priorities regarding the standardization depending on the domain. In that study, standards are not addressed individually, instead they are grouped as 10 standardization initiatives and the results are presented at that level, showing which efforts in standardization are most appreciated by the stakeholders. However, also in this case the study is outdated.

- Organization level

Researchers focus on the implementation at the company level as well. Azzouz et al (2018) focus on the use of digital artefacts in an international company across several European countries. They conclude that collaborative artefacts such are BIM execution plan (BEP), common data environment (CDE) and virtual design review (VDR) are not used at the same level, and that there are differences across the company's locations. The collected data shows the relationship between the digital maturity and institutional context. Morgan (2019) provides a case study following a single company and its BIM implementation over 15 years. One of three main managerial mechanisms for enabling digitalization in the organization is found to be: standards and policies (next to investment and leadership support, and skills development). Morgan (2019) divides the evolution of mechanisms into three phases and recognizes that the standards and polices become central to the work process in the final stage of evolution. Gercek et al (2017) recognize the need for a company's BIM implementation roadmap, especially in the countries which do not drive implementation at a national level (e.g. through a government BIM mandate). They align multiple BIM execution guidelines which cover BIM execution process, selected from a list of BIM standards and guidelines, but they do not refer to other BIM-related standards.

The present research addresses several of these standardization initiatives, however at a more detailed level – considering standards on an individual basis. Troiani et al (2020) investigated the influence of macro BIM adoption factors on BIM implementation within Italian companies. Their research uses a methodology similar to the one adopted in this paper, and concludes the importance of standardized deliverables and components, second to the introduction of BIM to relevant education curricula. However, the importance of individual standards was not explored.

In summary, BIM adoption and its success factors have been explored at multiple levels, from company to international levels (macro level). For instance, some of the mentioned works discuss limits in terms of adherence to standardized processes, in others, the limits refer to a lack of coverage of disciplines and sectors. However, it is found that BIM capability measurement is not agreed upon. While various standards and guidelines have been investigated, the relationship or correlation between the BIM standards adoption and implementation of BIM concepts is not explicitly investigated. Yet, it is interesting to note that the BIM standards are created to impact the implementation of BIM concepts, which is what this research explores. The most important challenges identified in the literature in relating the standards with BIM implementation will be pinpointed within this research.

Methodology

Methodology overview is presented in Figure 1. This work aims to gain an insight into the use of BIM standards and concepts in Europe. A systematic literature review was first conducted using the Scopus database. The search was performed in Mai 2022 with the terms "bim adoption" or "bim implementation" and "standard*", and by searching through titles, keywords and abstracts. The search initially returned 173 documents. After the selection based on the title 37 documents were excluded. 115 papers were excluded based on the abstracts, which left 20 research papers. These were read and the content of 16 was deemed relevant. Their analysis is reported in the background section of this paper. The literature review

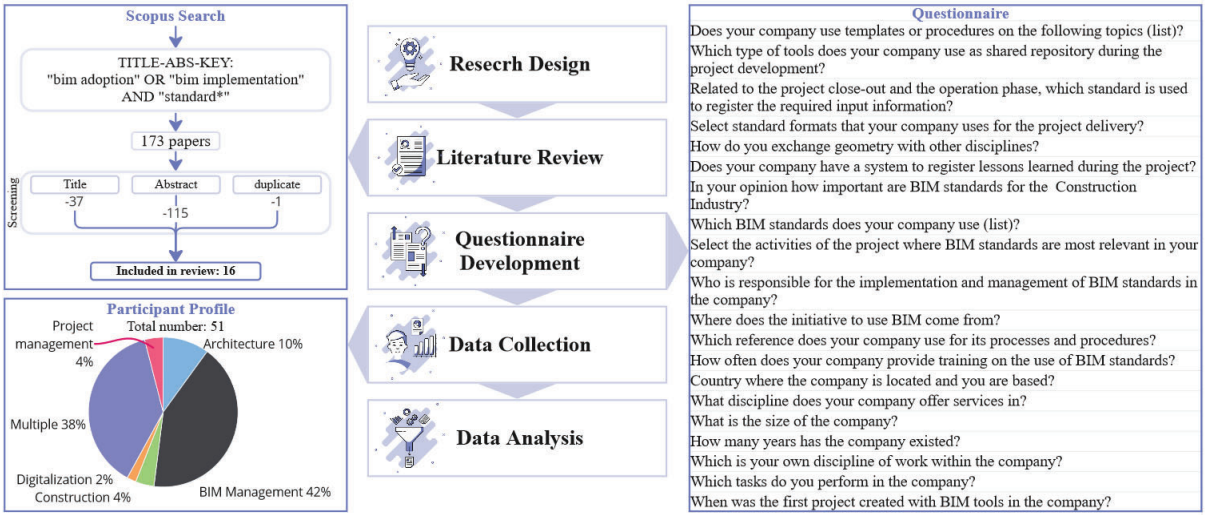

Figure 1 Methodology overview

is performed with the aim to identify existing work on adoption of BIM standards and implementation of BIM concepts, to setup the questionnaire and to draw conclusions after analyzing the results of the survey.

Later a questionnaire was created to investigate the levels of digitalization in the AEC industry, particularly the use of different concepts in performing daily business activities, different standards regulating the use of digital concepts, and the company profile. The questionnaire was divided into three parts: organization and personal profile, implementation in the company, and user view on importance of standards. There were 23 questions with three open ones. Literature review primarily served for identifying BIM concepts and standards. The survey investigated challenges and those have been then compared with literature review results. The investigation is focused on the adoption of individual solutions described and prescribed in various standards, such are shared repositories, information exchange requirements and formats, information delivery manual (IDM), BIM execution plan, IFC. The questionnaire was distributed in multiple ways between June 2022 and January 2023. It was first presented to the audience of the 2022 EC3 conference, where the attendees could go to the link and fill out the questionnaire. Afterwards it was shared on LinkedIn through multiple profiles. Finally, personal communication (e.g. emails, LinkedIn) was used to promote the questionnaire. It is therefore not possible to say what the response rate is, since the questionnaire was publicly available, and 52 responses were collected. Different professional domains have been included, as the standards now do not target a single-domain audience.

Data analysis first included cleaning up the received data, an especially important step for the open questions (typos or different inputs with the same meaning). The data has been organized and analyzed with MS Excel. The answers were evaluated, starting with the use of standards, and focusing on the ISO 19650 series. Results of each question were summarized and a comparative analysis performed. Then, answers from same users were compared with one another, so specific patterns in standard adoption could be identified. Multiple answers were investigated with logical operations to identify similarities.

The results of the analyzed data were related back to the existing literature and finally, suggestions for BIM implementation and standards adoption have been presented in the findings. The suggestions deliver points of attention which pinpoints the most important problems causing divergences between BIM implementation and standards adoption.

Results

The organization and personal profile part of the questionnaire deals with the profile of the company and the respondents. 62% of respondents work in BIM management, 23% architecture and 19% construction. Respondents were from 20 European countries and or active across multiple countries. Most common tasks which they perform are BIM management (64%), management/CEO (40%), design authoring (35%), quantity take-off (21%) and scheduling (19%).

A "BIM department" is responsible for the implementation and management of BIM standards in 71% of cases, but sometimes also the "design team" covers that role (39%). The BIM adoption is driven from the company itself in 90% of cases, by government (31%) or by an external company or investor (27%). The respondents reported that their companies use company-specific standards in 67% of cases, best practices – 60%, international standards - 44%, and country-specific standards – 35%. The processes and procedures are not standardized in 15% of cases. Following information was also noted: country where the company is based, size of the company and how long it exists, and when the first project with BIM tools was created. The type of services which the company provides, and the frequency of providing training for BIM standards for the employees have also been investigated.

As the adoption of standards is the focus of this research, respondents were asked to state which standards they use. The list of BIM standards is taken from CEN TC 442 (CEN-CENELEC, 2022). Figure 2 depicts the answers regarding the use of individual standards. It shows that BIM-related standards are generally used under 50% except for the 19650 series (between 57% and 71%). At least one (any) of the 19650 standards is used by 68% of the total number of respondents. The rest of the research focused on the 19650 series and more exactly how the use of the standards series correlates with the other results of the questionnaire.

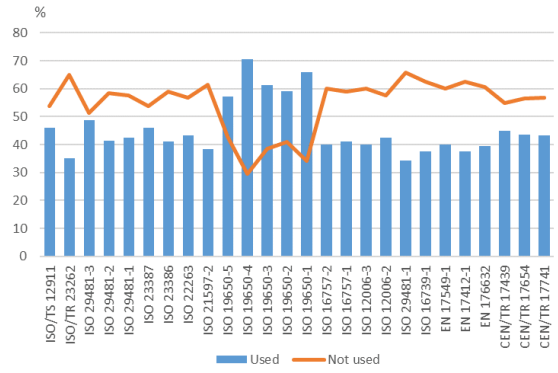

Figure 2: Use of BIM standards

The familiarity with BIM and related concepts in the group of correspondents is significant: they generally use multiple BIM concepts, however, the number of concepts they used varies. Individual BIM-related templates and procedures are in average used sometimes (2,2 on the scale 0 to 4). Use of templates and procedures on BIM-related topics is presented in Figure 3. Notably, IDMs and risk register are used less commonly (1,5 and 1,6

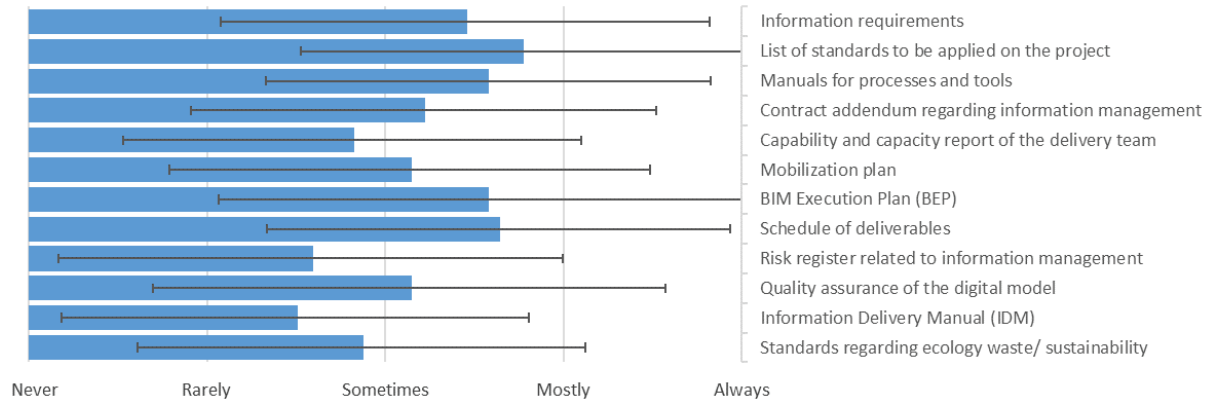

Figure 3: Use of templates and procedures

respectively), while the information standard and information delivery plans are used more frequently (2,8 and 2,6 respectively).

The users showed great awareness regarding the other investigated concepts, such as shared repository during the project development. Industry specific shared repositories are used by most of the users (79%), usually in combination with ad-hoc (generic) tools (65%) such are local servers or Dropbox. Only 6% of the respondents do not use a shared repository. Regarding the project operation phase, the users deliver required information in various ways, predominantly IFC schema (60%), while 29% use COBie (29%). Note that 33% use bespoke methods. Registering of information for operation phase was not performed by 23% of stakeholders. The project delivery almost always includes PDF files (89%), however diverse other means are also used: IFC or native building models (more than 70%) as well as 2D drawings and alpha-numerical documents (67%). The geometrical information is predominantly exchanged with open schemas such is IFC (71%), proprietary formats (65%), CAD drawings (52%), but also sometimes with physical or digitized documents (42%). Most of the respondents' companies have a system to register the lessons learned during the project (54%), but 40% do not. The importance of standards is generally considered to be very high (71%). Only 8% of the respondents do not use any standards. Standards are used primarily for modelling (71%), data exchange (65%), project management (50%) and project requirements (46%).

The answers describing the BIM concepts adoption and the company profile have been compared with the answers about the ISO 19650 series. The most interesting associations have been presented later in this paper.

The causal comparative analysis can be noticed in the case of the ISO 19650 series – awareness of procedures and templates relates to the use of the standard in 75% of the answers – the users which use any of the ISO 19650 series are more aware of BIM-related procedures and templates than the average. Each standard from the series ISO 19650 is used at least in 57% of cases. The responses regarding this standard series were further assessed to identify possible relations with the technologies and company profile.

The type of the shared repository used for projects does not have associations with the use of ISO 19650 series, although the ISO 19650-1 defines the functionalities required from the shared repository – almost a third of cases shows contrary results, where a standard is used, but a shared repository not. The respondents using COBie are also familiar with ISO 19650 in 87% of cases (13 out of 15). The 19650 series users mostly exchange proprietary formats (72%), however, other means of data exchange like 2D drawings, alpha-numerical data, IFC schema or PDF are also common with more than 50% of the respondents reporting using them. ISO 19650 series is used at least 74% in the cases when the BIM initiator in the company is own initiative, external company or investor, or government or regulatory body. Almost all (96%) users which reference international standards for their processes and procedures also use the ISO 19650 series. The use of ISO 19650 is 100% for the respondents from the UK, Ireland and internationally operating users (single answers per country were excluded). Besides them, at least two responses are collected from the following countries: Austria, Estonia, Finland, France, Italy, Portugal, Romania, Serbia and Spain. The companies offering plumbing, mechanical and electrical engineering have 100% use of the standard, followed by the companies offering BIM management services (94%). The users familiar with the standards are predominantly in BIM management domain within their companies (78%).

Discussion & Conclusion

The data analyzed show that users of ISO 19650 series, provide mainly BIM management services, the driver to use BIM varies, and they are geographically based in the UK and Ireland. Importance of standards is generally recognized, but individuals are not personally aware of many standards which are regulating the BIM use (Figure 2). The results show advanced implementation of BIM concepts by most of the interviewees, such is the use of shared repository or exchange data formats, as well as a general awareness regarding BIM-related templates and procedures. Size of the company and lifespan do not influence the use of standards.

The adoption of BIM standards does not stand in relation with the implementation of BIM concepts. Respondents were not aware of several standards, that define the concepts they use. However, the users still show great awareness of BIM, especially the technology and procedural aspects covered in those standards. Other standards, beside the official published by ISO/CEN, are also adopted; they are published by organizations with national prescriptive and descriptive channels (e.g. mandates and guidelines), or through the standardization of technologies and processes which the end users adopt.

Respondents generally find standards important, however they are still not widely used. Only the ISO 19650 series standards are found to be more popular. Comparison of the standards' use with the implementation of specific technologies or processes shows no direct association. The largest interest in standards exists in MEP companies, followed by BIM management companies, infrastructure and sustainability. The standards are most used in the UK which mandates the use of BIM for centrally funded public works, and Ireland which does not have mandates.

Conclusions drawn from the presented results and the literature related to standards adoption are:

- This paper shows for the first time, and it has not been explicitly stated in the literature, that the use of standards related to the BIM concepts does not necessarily imply the implementation of same BIM concepts expressed in the standards themselves. This might express that, even if professionals do not know the name/number of standards, they are anyway implementing the concepts. Another option could be that BIM implementation is currently mainly driven by best practice without following specific standards. This lack of standardization might create interoperability issues across applications, organizations and markets.
- Stakeholders have diverse interests in standards, depending on the domain, country, or implementation of specific BIM concepts. This is visible from the survey and supported by the literature review (e.g. Hijazi et al, 2017).
- Standards need to be diffused through different channels to reach the end users, such as by introducing specific mandates (at national level or by client/investor), guidelines, and integrated through technological solutions that facilitate user adoption (as it was previously stated by Alreshidi et al, 2017).

The results show that the standards are useful in the industry, but awareness and adoption by professionals is still limited. The standards diffusion strategy needs to be improved, and their integration with technology solutions should be simplified. For the end users which are not directly engaged with the interdisciplinary work, the technological implementations of standards are more relevant and useful than standards themselves, such are schemas or templates, which can be noticed from the low usage of IDMs which also lacks technological implementation. A diffusion strategy of standards should be implemented along with the creation of a standard. It would be useful having indications and guidance on how to introduce standards to the industry and constantly monitor their adoption at different levels such as national, organization and project levels.

Limitations of this research are primarily found in the number of received answers with a non-uniform number of respondents across the European countries. Thus, the number of responses cannot provide a detailed overview of the country in the European area, but it can help to identify trends.

In the future the results should be validated with a wider audience, supported by qualitative data via semi-structured interviews with professionals to investigate the topic further. This will allow a better understanding of blockers and enablers in standardization adoption.

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