ROLE OF AN INNOVATION COMMUNITY IN SUPPORTING BIM DEPLOYMENT: THE CASE OF BUILDINGSMART NORWAY

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ABSTRACT
The construction industry is notorious for being slow to adopt technological innovations. One way to support the industry and accelerate the uptake of technologies is to establish open standards. This paper examines how the buildingSMART community helped the Norwegian construction industry in their attempts to implement Building Information Modelling (BIM) with open standards. The interventions were identified by using the Institutional Intervention Model in the data analysis. Data were collected through interviews with industry experts affiliated with the Norwegian chapter of buildingSMART. The interviewees were selected for their central role in the community and for working hands-on with developing open standards, processes, guidelines and educational resources for BIM implementation. Our findings show that the community has succeeded in their efforts to further BIM-related competences in the industry. Moreover, we document how the interventions of non-profit communities have contributed to creating tangible business values for firms in the construction industry. The insights from this study have implications for other industries or countries which desire to develop innovations based on a community approach.
Keywords: building information modelling, construction industry, open community, open innovation.

1 INTRODUCTION

Innovation can help the construction industry to increase efficiency, corporate performance and sustainability [1]. However, the construction industry still lags behind other industries in innovation activities because of different barriers derived from its nature and context [2]. The low uptake of innovation adoption also happens when construction practitioners digitalise with building information modelling (BIM) technology. BIM supports the shift in construction projects from paper-based to model-based design [3], [4]. This technology also assists in the change from fragmented construction processes to an integrated and collaborative working style based on Information and Communication Technology (ICT) platforms [5], [6]. Besides development in separate organisations, construction practitioners also advance innovation through communities [7], [8]. We contribute by expanding the literature on construction communities and innovation, particularly in BIM development. Our research question is: "How do construction communities advance BIM technology?".

To answer this question, we interviewed eleven industry experts affiliated with the Norwegian chapter of buildingSMART. Moreover, to understand how the community intervenes in industrial practice, we used the Institutional Intervention Model [9] to make sense of the interview data. This model helps to disclose how the community's activities influence the adoption and use of BIM technology. The paper aims to broaden understanding of innovation activities in construction communities by describing the role of a professional association for innovation in the construction industry and explicating how construction companies can obtain business value from community work.

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The paper is organised into six sections. The first section introduces the research question and objectives. The second section briefly describes BIM technology, openBIM and the buildingSMART construction community. The third section presents the theoretical lens guiding the data collection and analysis. Then, the method section introduces the case study, followed by a presentation of the findings and discussion. Finally, the conclusion summarises key contributions and topics for further research.

2 BUILDING INFORMATION MODELLING AND INNOVATION COMMUNITIES

2.1 Building information modelling

BIM is an ICT innovation supporting data sharing and collaboration in construction projects. In such projects, different disciplines, such as architecture, structure and mechanics, perform various tasks, including design, implementation, maintenance and management, requiring extensive collaboration among the construction partners. BIM software provides a platform for this collaboration, integrating separate construction processes into an information model of the construction project. The model typically consists of non-geometrical and geometrical data of the building components. While geometrical data include physical measurements, non-geometrical data support construction management with information such as scheduling, costs, material types and relationships among components. The main idea of BIM is to create a digital object that includes all relevant data and make these data available for relevant parties within the construction life cycle. The results of BIM use include but are not limited to fewer errors, lower expenses and shorter duration [10], [11]. To gain benefits from BIM, construction organisations have invested in BIM development through various options, such as open innovation. An example of the open approach to BIM development is openBIM.

An initiative of buildingSMART, openBIM is "a universal approach to the collaborative design, realization, and operation of buildings based on open standards and workflows" [12]. Simply put, openBIM is a digital language for the open and free exchange of information on the built environment. With openBIM, construction partners can work together regardless of the software they use through a vendor-neutral data exchange format. Regarding "closed BIM", the BIM tools are from just one vendor [13]. Since construction involves different disciplines and tasks, it is difficult for a single software vendor to provide necessary tools that match all construction demands. Thus, construction companies use different software systems. These software systems should feature interoperability for effective collaboration. If construction data cannot be exchanged from one software system to another, then construction practitioners must process the data every time they are received. Gallaher et al. [14] reported that the cost of correcting software interoperability in the US was a financial burden to the construction industry. Construction owners and operators bore about two-thirds of this cost, while the remaining cost was borne by contractors, suppliers, architects and engineers. Reducing this type of economic waste was the main reason for establishing the Private Alliance in 1995 with 12 companies. The main purpose of this alliance was to achieve interoperability through full information exchange. The Private Alliance became buildingSMART in 2008. The core principles of buildingSMART are openness, neutrality and non-profit [15], together presenting an open approach to developing digital standards for the built environment. The products of buildingSMART are open standards, including the Industry Foundation Class (IFC), the International Framework for Dictionaries (IFD), the BIM Collaboration Format (BCF) and the Integrated Delivery Manual (IDM). Although some problems, such as data loss and misinterpretation, still happen [13], it is clear that the construction community has made progress on digital innovation in construction.

2.2 Innovation community

Open innovation, coined by Chesbrough [16], is an approach to innovation through communities. Open innovation has promoted technology development in various industries, such as chemical, ICT, consumer-product, automotive and retail industries [17]–[19]. Open innovation is "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" [20]. The open approach helps technology development overcome inefficiencies, such as rising development costs, shorter product life cycles and underused patents [21]. Open innovation facilitates knowledge to flow in and out of the company boundary, creating inside-out and outside-in types, respectively. Companies can also perform a so-called "coupled process" which allows knowledge to flow in both the inside-out and outside-in directions [20]. By facilitating knowledge flows, the open approach provides new development paths for underutilised ideas. This approach encourages companies to apply external ideas if they are considered better than internal ones [22].

A community can be a group of individuals and/or firms based on voluntary participation [23]. Communities play an important role in innovation by developing technical standards, organising interactions among members and encouraging members to create their own start-ups to commercialise newly developed technologies [24]. These interactions form the basis of a community. Through interactions, members can share their knowledge, form collective solutions and create joint artefacts [24]. The joint production is an important indication of a successful community [24].

3 THEORETICAL LENS

King et al. [9] reminded us that innovation is a process of turning an invention into a usable form, where an invention is a new idea or a new product. Innovation may also be a product developed from an invention. To explore how an organisation intervenes in ICT innovation, King et al. [9] proposed a model, referred to as the Institutional Intervention Model in this paper, which includes six forms of institutional actions across two dimensions (Fig. 1).

The first dimension is influence – regulation, expressing the extent of persuasive or compelling control. The second dimension is about supply-push and demand-pull forces driving the innovation. While the willingness of potential users to use the innovation generates demand-pull forces, the supply-push forces derive from the innovation itself [9].

	SUPPLY-PUSH	DEMAND-PULL
INFLUENCE	Knowledge building Knowledge deployment Subsidy Innovation directive	Knowledge deployment Subsidy Mobilisation
REGULATION	Knowledge deployment Subsidy Standards Innovation directive	Subsidy Standards Innovation directive

Figure 1: Dimensions of Institutional Intervention. *(Source: Adapted from King et al. [9].)*

Table 1: Six forms of institutional action. *(Source: Adapted from King et al. [9].)*

Form of action	Institutional action
Knowledge building	Creating knowledge bases that are necessary for innovative activity. Typically, conducting and funding basic research belong to this category. Governments may also mobilise large corporations or their agencies to conduct research on particular topics of national importance.
Knowledge deployment	Facilitating the dissemination of new knowledge. For example, introducing individuals and organisations to knowledge of an innovation, creating repositories of technical facts, providing training.
Subsidy	Using the resources of an organisation to reduce unavoidable costs and risks to innovators. This action includes the funding of prototypes, internally producing goods and services from an innovation, supporting complements for using innovation, and reducing barriers to the production of an innovation.
Mobilisation	Encouraging external individuals and other organisations to have the same opinion on innovations. The main instrument for mobilisation are promotion and awareness campaigns.
Standard setting	Establishing socially constructed agreements among organisations interested in using an innovation. The implementation of standards is voluntary, but it can become mandatory if enforced by law.
Innovation directive	A command to produce, use or facilitate innovations. Directives appear in requests for a particular technology, investment in research and development, requirements to use particular products, etc.

An organisation can increase the supply of a particular technology to the market through various actions, such as providing financial and personnel support for research and development [25]. These two dimensions provide four different contexts of innovation. Based on the context, an organisation can perform appropriate institutional interventions to facilitate innovation. Table 1 describes six forms of institutional actions.

Each innovation requires appropriate interventions for development, and organisations have different ways of adopting innovations [9]. Furthermore, an organisation can change its role in the innovation process depending on the context [9]. Since the Institutional Intervention Model can provide a framework to understand the context of ICT innovation, this model is a suitable theoretical lens to guide data collection on how the buildingSMART community advances openBIM in the construction industry. In the context of this research, the buildingSMART community and its member organisations use a combination of institutional actions to develop openBIM innovations. An individual organisation, for its sake, exerts the demand-pull force, such as requesting training programmes from the community. This organisation can also perform the supply-push force, such as funding

prototype development to benefit the community. The actions which happen inside the network of the studied organisation and influence openBIM development will be considered as institutional actions.

4 METHODOLOGY

We conducted an interpretive case study of the buildingSMART Norway Chapter (bSN), a member of buildingSMART International. The establishment of bSN began from the visit of a Norwegian construction delegation to the Singapore Building and Construction Authority in 2003. During that visit, the Singaporean agency showcased how to use BIM and IFC for electronic plan checking. Impressed by this BIM application, the Norwegian delegation decided to promote openBIM in Norway by performing an establishment project. This project led to the establishment of bSN in 2010. Since then, bSN has conducted various BIM-related activities that seek to positively influence the dissemination of openBIM. These activities include participating in standardisation, organising hackathons, preparing openBIM training, organising annual conferences and meetings, arranging different discussion groups and providing BIM-related information [26]. In 2010, Statsbygg, the Norwegian Directorate of Public Construction and Property, began to request the use of openBIM in their projects [27], making Norway one of the first countries to request open BIM standards. Statsbygg was also an active member in the establishment of bSN. Besides Statsbygg, other Norwegian organisations have also adopted the open approach to BIM, such as the National Rail Administration (Bane NOR), the Defence Estate Agency, the Public Road Administration, and various software vendors and consultants. At the time of data collection, bSN had 131 organisation members, like government agencies, software vendors, contractors, consultants, universities and standardisation organisations. bSN is an example of openBIM promotion through the community. With diversified activities and different types of members, bSN is a suitable case to explore how a community advances BIM technology in construction.

We prepared a list of 20 potential interviewees and contacted them for appointments. The criteria for selecting interviewees were as follows: (1) Having experience with BIM and with bSN's activities; (2) Having experience with decision making on technology adoption in their organisations; (3) Being active within bSN and within construction community activities; and (4) Representing different types of bSN members. Our interview guide had two sections. The first section focused on the working experience and background of the interviewees. The second section consisted of nine open questions on the interviewees' activities related to BIM and bSN participation. Based on the Institutional Intervention Model, these nine open questions revealed different forms of bSN's actions. The interviewer also asked follow-up questions to get as much detail as possible from the experience of the interviewees.

Table 2 shows an overview of the interviewees. From November 2018 to January 2019, we conducted 10 interviews with a focus on the decision makers from the bSN members because they can influence the knowledge flow between their organisations and bSN. The contacted bSN members were from different organisations, including those in the private sector, in non-profit companies and in academia. Eight interviewees were at the director level, while three were company founders.

The recorded interviews were transcribed and analysed in NVivo 12. The Institutional Intervention Model formed the framework for coding, but we also arranged one category for any activity that was different from the six forms of action. Since this paper focuses on the open innovation community, the case study needed to have an open boundary. This means the analysis investigated any activity leading to openBIM innovation with the participation of bSN members, also including activities not organised by bSN. Other relevant documents and information from bSN were also part of the collected data.

Table 2: The list of interviewees.

Interviewee no.	Company type	Level	Experience (years)
Interviewee 1[i]	Construction association[n]	Director	+20
Interviewee 2	BuildingSMART Norway[n]	Director	+20
Interviewee 3[i]*	Software vendor	Founder, Director	+20
Interviewee 4[i]*	Software vendor	Founder, Director	15–20
Interviewee 5[i]	Software vendor	Founder, Director	+20
Interviewee 6[i]	Software vendor	Director	+20
Interviewee 7	Consultant	Manager, strategy lead	15–20
Interviewee 8	Standardisation[n]	Director	+20
Interviewee 9	Standardisation[n]	Project manager	+20
Interviewee 10[i]	University[n]	Senior engineer	10–15
Interviewee 11*	University[n]	Associate Professor	15–20

*Holds a PhD degree, i: Has experience from ICT projects, n: Non-profit organisations.
One group interview was conducted with both Interviewee 8 and Interviewee 9.

5 FINDINGS

In addition to institutional actions, the data also revealed what motivated the interviewees to engage in community work. This section describes the motivation of members and the institutional actions in bSN. bSN uses various communication channels, including annual conferences, forums, sub-forums, slack online forums, workshops, group meetings, Oslo BIM meetings, newsletters and websites. bSN members gather via these communication channels for discussions on openBIM use and development. The discussions happen at both the whole community and sub-group levels. The results are demands for new standards, experience sharing and joint products related to open standards. The joint products can be new applications of openBIM, new adoption processes, training programmes, etc. Therefore, these communication channels are essential for bSN to intervene in openBIM development.

5.1 Motivation to join the bSN community

The establishment of bSN was successful because of the strong leadership of the steering committee. The leaders of the bSN establishment project had extensive experience in various leading positions in buildingSMART international and different construction organizations. The leaders' reputation and management made the members contribute to the community:

> "There was a good sense of community across companies and organisations and there was a lot of willingness from each organisation and community to spend their own time and own money to get this going. So a lot of individual efforts combined into a big community level controlled by a reasonably strong leadership". (Interviewee 4)

Following the inspiration on openBIM from the bSN leadership, bSN members actively contributed to various buildingSMART activities, particularly IFD development,

standardisation and summit organisation. The bSN members received no payment for their contributions to the community.

The bSN members saw the benefits for their business from contributing to the community, and the bSN community shared a belief in the advantages of openBIM, which benefited all parties in the construction value chain:

> "All of us have a sort of grounding belief that open standards are the only way to make innovation flourish". (Interviewee 3)

> "Why we have supported the dictionary [IFD] development is because we've seen the future value for the community and for us". (Interviewee 5)

Anyone with innovative ideas on buildingSMART deliveries can develop their products or services. Various members of bSN chose openBIM as their core competency and have invested in open standards; e.g., Catenda creates a cloud-based collaboration platform supporting IFC files, while CoBuilder develops product data templates based on IFD.

Although their work for the community might be different from their business, by showing their competence with openBIM, they gave other members the impression that they possessed good skill sets and thus associated their products with good quality. Thus, the interviewees believed their contributions to the community could create benefits for their business.

> "People in the buildingSMART community almost know us for the data dictionary. That is not what we are about… It's been a rough idea that we didn't want to be in the buildingSMART community pushing our product…We were trying to contribute in a good matter that creates trust".

> "I think people have seen that there are some good skill sets behind someone they can trust, and when they hear about our product, immediately they will think it must be a good product because there are good people behind it". (Interviewee 4)

Also, the bSN members wanted to take social responsibility by contributing to the construction community. According to Interviewee 6, improving efficiency in construction can bring benefits to society, such as affordable houses, a better environment and so on. He believed that digitalisation was the right solution to the construction efficiency problem.

> "The construction industry consumes 40% of energy use but creates 40% of solid waste because of bad communication and bad processes. That is the difference from other industries which are digitalised more and use more technologies to reuse the waste". (Interviewee 6)

Despite the mentioned advantages of bSN, some interviewees still expected changes for innovation to happen faster. They argued that bSN and buildingSMART were suitable for meeting people but inappropriate for making changes and decisions.

5.2 Knowledge building

bSN members have created new technical knowledge on openBIM in academic, industrial and collaboration projects. Regarding academic projects, the researchers in the bSN member universities have published research articles and guided student projects on openBIM. In 2018 and 2017, bSN introduced 113 student projects related to openBIM to the community. Besides academic knowledge, the guidance also includes connecting to companies for accessing data. The industrial projects create practical knowledge on openBIM, such as

software tools, the Digital Roadmap and the results from the openLab hackathons. The Digital Roadmap is a strategy for digitalisation in the Norwegian construction industry with a vision towards the year 2025. This strategy suggests Norwegian construction organisations should digitalise together based on BIM and open standards. At the time of data collection, bSN was creating an innovation programme to push joint activities.

> "We are now creating an innovation programme for this network for innovating and developing digitised ways of working together… We need to innovate in solution and standards". (Interviewee 2)

A typical activity in this programme are the openLab hackathons, in which bSN supports the problem owners to organise a competing ground for innovative solutions. The results from the hackathons might lead to standardisation or practical solutions for the problem owners. Besides the project's focus on the Norwegian market, bSN also participates in the development of buildingSMART deliveries, particularly on the IFD. This serves as a way for bSN to share their experience and products on openBIM to the community.

In addition to conducting research in their domains, academia and industry members also collaborate for mutual benefits. On the one hand, the universities invite industrial practitioners to give guest lectures, which provide essential updates to the educational programmes. On the other hand, the industrial companies need researchers' expertise for their product development. In this way, the companies can absorb external knowledge for their innovations.

5.3 Knowledge deployment

bSN supports the dissemination of openBIM not only in Norway but also in other countries through presentations and networking among their members. These members are either leading working groups in buildingSMART International or they have experience with openBIM implementation in Norway.

Besides, bSN organises a repository of open standards on their website. Construction practitioners can find relevant information – including an overview of openBIM, events, annual competitions, open standards and competence services, such as teaching curriculums and certification, training courses and an online portal for certification. The website also provides student theses on openBIM. The website represents an archive to explore what students can do with openBIM in their educational programmes.

5.4 Subsidy

The bSN community has two schemes of funding for innovation. The first scheme, managed by the steering committee, focuses on bSN activities. With the funding from the membership fee, bSN employs four full-time staff for the administration board. This staff manages activities in Norway and participates in standardisation, maintenance of communication channels and the openBIM repository, as well as research collaboration with members and other organisations. With this full-time staff, bSN has become a formal entity dedicated to openBIM development in Norway. This has resulted in diversified channels for innovation and more members joining bSN.

The second scheme, derived from the organisational members, aims to create innovative solutions for the members' interests. The funding comes from the members' budget. For instance, based on a request from Statens Vegvesen – the Norwegian Public Roads Administration, bSN organised a hackathon to generate ideas on applying open standards for

the planning and execution phases in road and bridge projects. Statens Vegvesen paid all expenses of the event.

> "A hackathon is an activity in a large project of Statens Vegvesen. Statens Vegvesen came to us and said they wanted to use open standards for model-based project planning and execution and see how they can use open standards…So bSN started a project, and hackathon is an activity in that. We also have other members who come to us, and they want direct support or use buildingSMART as an arena for innovation". (Interviewee 2)

Besides hackathons, bSN members also conduct their own research projects. The building research organisation, SINTEF Byggforsk, for instance, sponsored the creation of a cloud-based collaboration platform for seamless information flow in construction projects. The prototype of this platform served as the foundation for creating a start-up later on. The support from SINTEF reduced the risk and cost in the initial phase of the development, and thus stimulated innovation on openBIM.

5.5 Mobilisation

While deployment actions provide openBIM with knowledge, mobilisation actions require more interactions with potential users. bSN used this form of action to persuade potential users to believe in openBIM capacity. Mobilisation can be combined with deployment actions in the community activities. bSN encourages other construction practitioners to adopt openBIM through offline events. The offline events include annual conferences, meetings and workshops. There is no restriction on joining the discussion, and anyone can use the bSN communication channels to discuss how to adopt openBIM with the community. In addition, bSN inspires students to apply openBIM in their projects with education awards. bSN members actively approach students for promoting openBIM.

> "We engage universities and vocational schools. We have a good relationship with most of the vocational schools that educate people with BIM technology. We also have relationships with NTNU (Norwegian University of Science and Technology) and OsloMet (Oslo Metropolitan University) … We do try". (Interviewee 4)

5.6 Standard setting

The core of openBIM is about open standards. Therefore, developing standards is an important task of bSN, and the members understood that they should standardise together.

> "Instead of starting up an initiative here and there… they understand that if they want to influence their future in terms of profession or business, they should come together here [for making standards]". (Interviewee 8)

Besides buildingSMART International, bSN members hold leading positions in technical committees related to BIM in three other standardisation organisations, namely Standard Norway, the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO). According to Interviewee 8, Norway initiated the European standardisation in the BIM domain. The active participation at different geographic scales of standardisation resulted in two positive consequences. First, the bSN members were familiar with European and ISO standards on BIM in the preparation phase. Therefore, it was convenient for them to do business in countries that adopted those

standards. Second, bSN could learn how to improve the quality of the standards by utilising standardisation processes and resources in CEN and ISO.

5.7 Innovation directive

Although the bSN community has been active in developing open standards, the application of openBIM was low until a client formally requested it. Interviewee 7 commented that "when Statsbygg said that all our projects would require openBIM from the year 2010, then the market changed, and the industry also changed". In the case of bSN, Statsbygg supported the development of open standards and has become the market leader in using those standards. Interviewee 8 suggested an example model for the implementation of open standards, which was "Standard Norway develops standards, Statsbygg chooses which to apply, and bSN supports the implementation".

6 DISCUSSION

Innovation communities focus on pushing innovation development through the voluntary contributions of members. We argue that the success of such communities relies on how members perform innovation together. Our analysis suggests that the members participate in the bSN activities because of inherent benefits from the community activities. The collected data shows that bSN performs six forms of institutional action for innovation (see Table 3).

6.1 How buildingSMART Norway contributed to openBIM development

Regarding innovation communities, leaders should have a strong technical contribution and be able to bind the community together [28]. In the case of bSN, the leader of the establishment project was successful in setting the digitalisation vision for the community as specified in the Digital Roadmap. This vision and the leader's reputation made the members believe they should digitalise together and develop BIM innovation based on the open approach.

Table 3: buildingSMART Norway innovation activities.

Form of action	buildingSMART Norway innovation activities
Knowledge building	Creating the Digital Roadmap and product data templates, organising openLab hackathons, conducting academic studies and research projects, guiding student projects
Knowledge deployment	Attending various events as keynote speakers, publishing case studies, providing an online tool for certificates, advancing a training curriculum, creating the open standard repository
Subsidy	Providing funding for an administration board with four full-time positions, conducting projects to make BIM tools, sponsoring hackathons and research projects
Mobilisation	Organising education awards, presenting openBIM to different audiences, performing guest lectures, making marketing videos
Standard setting	Participating in standardisation in ISO, CEN, buildingSMART International, Standard Norway
Innovation directive	Requesting openBIM in public projects of Statsbygg, Statens Vegvesen

In addition to strong leadership, bSN members saw the benefits of participating in the community. The benefits have both commercial and social aspects. The commercial benefits come from the support for both the prototype and knowledge development. From the technology foundation, bSN members can perform further development to gain competitive advantages. This finding is in line with a study on the Linux Foundation community, where IT organisations not only adopted but also modified the Linux kernel to suit their business and strategic needs [29]. Furthermore, the technical contribution to the community can build relationships and trust among members, which might turn into business partnerships later on. Another benefit derives from social responsibility. We argue that social responsibility can be a promising driver for construction technology development in the digital era. How social responsibility supports digital innovation in construction might be an interesting topic for further studies.

bSN has performed six forms of institutional actions. However, knowledge deployment and mobilisation seem to be the key action forms to exert supply-push forces to the community. These actions from the community suggested that bSN members adopt openBIM. In return, bSN members demanded more support from the community to apply openBIM in practice. The members' requests resulted in knowledge building, subsidy and innovative directive. In the bSN case, the Norwegian community was aware of openBIM by early on participating in Private Alliance activities. After the visit to Singapore in 2003, the Norwegian delegates believed in the benefits of openBIM and decided to promote it in Norway. As a result, bSN members organised hackathons, supported BIM research, mandated openBIM use and performed other activities to apply openBIM. We argue that knowledge deployment and mobilisation are essential institutional actions to support the construction community in developing not only openBIM but also other innovations. We propose that further studies be conducted on institutional actions to broaden the understanding of innovation in the construction community.

6.2 Open innovation and construction communities

In the bSN community, the interviewees reported gaining benefits from open standards, such as the software companies that have built their business competencies from the community work. These companies have not only developed open standards but have also used these standards to build their commercial services. The openLab hackathons are other examples where bSN members organise events for creative ideas on problems raised in the community. The practice of the bSN community reflects how knowledge flows in and out of organisational borders. It also represents how companies can benefit from community work. More studies on this topic can contribute to the development of the construction industry and broaden the understanding of open innovation in another context.

If a company chooses open innovations as its core competency, then its management board must balance the tension between standardisation and customisation. Standardisation reduces fixed costs and offers efficiency, while customisation leads to high satisfaction but lower efficiency [30]. The more customisation an organisational member makes, the more active this organisation is in the standard development. For example, the software vendors that develop their openBIM tools often hold the leading position in the working groups for developing standards. Although the relationship between innovation and standardisation is still unclear [31], we would argue that the variety of standardisations might have positive influences on innovation. The relationship between how an organisation uses open standards and how this organisation contributes to innovation development might be an interesting topic to explore further.

6.3 Contribution and limitations

This paper contributes to the understanding of the influence of an innovation community on BIM development in the construction industry. Through the analysis and discussion, the role of bSN as a professional construction association was elaborated. The bSN members showed different levels of using open standards and participating in the community work. Also, the paper reveals how a construction company turns community contributions into business values. The following limitations of our study should be noted. First, our data collection did not include the voices of clients, contractors or research funding agencies. Second, all interviewees and interviewers used English as a second language, which might have affected the collected data. Third, all interviews took place in Oslo, Norway, and thus we could not identify any issues related to location constraints. Therefore, we propose expanding the study to include the remaining stakeholders and broadening the understanding of the impact of the open community on construction innovation in Norway and internationally.

7 CONCLUSION

In summary, this paper describes how the bSN community developed openBIM through different institutional actions. The bSN case study highlights the importance of the leadership as well as the motivation of members to contribute their resources for technology development. To support openBIM development, the bSN administration board might direct activities to knowledge deployment actions to form the foundation for innovative ideas. Besides, mobilisation actions are important to encourage construction practitioners to adopt openBIM. The bSN members, on the other hand, should consider subsidy actions for innovative solutions to their specific problems. Thus, innovations can flow into organisations and become new business advantages or core competencies of spin-off start-ups. To provide a better understanding of innovation communities, we have suggested topics of interest for further studies in the discussion. Although some limitations remain, this paper addresses the research question by providing an understanding of how a construction community advances BIM technology.

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