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Fostering process innovations in construction through industry–university consortium

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Abstract

Purpose – University research efforts have not been effective in developing lasting impacts on operations management in construction because of inadequate coordination between academia and industry. This study aims to describe the development of an industry–university (IU) relationship which has enabled the conduct of practically and scientifically relevant research.

Design/methodology/approach – Design science research was carried out between 2016 and 2019 to build a consortium between a university and 17 design, construction, technology and logistics companies for enabling process innovations in construction. The consortium conducted industry-funded research on various topics, such as takt production, lean design management, prefabrication, measurement of waste and business models supported by digitalisation. The academic and practical impacts of the consortium's research projects were investigated through a survey and in-depth company interviews.

Findings – The paper presents a conceptual model for creating an IU relationship to support scientifically and practically relevant research. The model includes network architects who mobilised consortium development and a joint governance body that developed a shared long-term vision and selected research topics based on this vision. The results show that using the model's approach, the consortium selected research topics that have led to both academic publications and process innovations in construction.

Originality/value – Using empirical data, this study describes how to create a win-win IU innovation relationship that enables the implementation of process innovations into the construction sector and, at the same time, the conduct of scientific research in construction management.

Keywords Process innovation, Operations management, Construction, Industry–university relationship, Consortium, Design science research

Paper type Research paper

Introduction

Research has shown that individual companies that collaborate with universities prosper in the long term (Santoro and Betts, 2002; Pizam *et al.*, 2013). However, Koskela (2017) stated that construction management research has not had a lasting impact on the construction sector because research problems and methods have not been aligned with the developments in the sector. This argument is part of the broader rigour–relevance debate in

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business and management research (Van de Ven, 2007; Bresnen, 2017). Following Ivory (2017, p. 387), the key question is how to ensure that theory building and management problem-solving are co-productive with one another.

Sometimes companies complain that academic research is not practically relevant. Academics usually respond by stating that universities aim to conduct theoretically relevant research that leads to the creation of new scientific knowledge. The challenge from the companies' point of view is that scientific knowledge cannot usually be applied as such in business operations (Gann, 2001). The new knowledge first has to be interpreted in the current context, but company representatives rarely have the absorptive capacity necessary to do so (Gann, 2001).

Innovation plays a critical role in the long-term prosperity of companies and societies through economic growth and increased productivity (Martin, 2012). However, the construction sector is conservative and slow to adopt innovations that necessitate changes in the project network (Tatum, 1988; Gann and Salter, 2000; Blayse and Manley, 2004). Collaboration between the construction sector and academia is key to a successful innovation process (Shapira and Rosenfeld, 2011). However, the collaboration between companies and universities is not straightforward, mainly because the two instances have different timespans. Companies often operate on a quarterly basis, whereas universities usually aim to look a couple of years ahead. As a solution to this collaboration challenge, companies and academia should "develop a shared space whereby the work being undertaken by the research community has meaning in both the academic and industrial worlds" (Aouad *et al.*, 2010, p. 389).

Previous research on industry–university (IU) innovation collaboration has reported on the forms of and motivations for collaboration and described the theoretical process for forming a collaboration relationship (Blayse and Manley, 2004; Aouad *et al.*, 2010; Ankrah and AL-Tabbaa, 2015). However, empirical research on the creation of IU relationships is lacking. This paper aims to fulfil this research gap by developing a conceptual model, based on empirical data, for creating an IU relationship, which is a shared space that enables the conduct of scientifically and practically relevant research. Thus, the paper contributes to the discussion on the rigour and relevance of construction management research by providing an answer to the question of how to develop a win-win relationship between several companies and a university.

The authors of this paper engaged in design science research and developed an IU consortium in 2016; as of fall 2019, the consortium now consists of a university and 17 design, construction, technology and logistics companies. The consortium aims to foster the transformation of the Finnish construction sector by implementing lean and digital process innovations. The consortium companies fund research by the university and commit to applying any relevant research results in practical projects. This practice is in line with the current call for the sector to take a more significant role in funding essential research topics (Aouad *et al.*, 2010).

The paper is structured as follows. First, previous research on implementing process innovations in construction and IU collaboration is discussed. Then, the empirical research methods are presented. After that, the development process of the IU consortium is presented, along with the findings on the impact of the consortium's research. Then, the conceptual model for creating a win-win IU relationship is presented and discussed. Finally, the limitations of the study and theoretical and practical implications are provided and suggestions are made for further research endeavours.

Implementing process innovations in construction through industry–university collaboration

The construction sector involves multiple loosely coupled actors that utilise several different economic revenue models (Dubois and Gadde, 2002a). Additionally, business is generally conducted in projects involving multiple companies (Tatum, 1988; Gann and Salter, 2000; Blayse and Manley, 2004). The implementation of innovation in this context is complex, as it necessitates the willingness and actions of several actors (Bygballe and Ingemansson, 2014).

This study divides innovations in construction into two broad categories, product and process innovations. Product innovations are changes in the way resources are used across companies, and they affect the end product of a construction project (Bygballe and Ingemansson, 2014). Process innovations, in contrast, are ideas that are implemented into the inter-organisational practices in a construction project (Hartmann, 2006).

The implementation of process innovations requires that multiple companies change their practices (Taylor and Levitt, 2007). Rahman (2014) found that the biggest hindrance for implementing process innovations was related to costs. The decision to start piloting a new method is often impeded by high initial costs to set up new production methods or higher overall costs compared to traditional methods (Rahman, 2014). Blayse and Manley (2004) suggested a five-step process for innovation implementation in a construction company. The first step is to recognise an opportunity for innovation, after which a climate for innovation needs to be developed, forming the second step. During the third step, new construction technology is provided. The fourth and fifth steps cover the experimentation of innovation and its implementation into projects, respectively.

Xue *et al.* (2014) conducted a literature review on construction innovation and concluded that the topic is typically researched from the perspectives of collaboration, culture, innovation process and drivers. The authors divided the antecedent factors of construction innovation into two broad categories of collaboration and culture (Xue *et al.*, 2014). *Collaboration* entails inter-organisational cooperation (Bresnen and Marshall, 2000; Dulaimi *et al.*, 2002), IU relationships (Slaughter, 1998; Dulaimi *et al.*, 2002; Aouad *et al.*, 2010) and complex product systems (Winch, 1998; Barlow, 2000). *Culture* entails innovation climate (Blayse and Manley, 2004) and leadership (Tatum, 1988). This paper falls under the category of collaboration; more specifically, the implementation of process innovations in construction through an IU relationship.

IU collaboration refers to the interaction between industries and universities for knowledge and technology exchange (Ankrah and AL-Tabbaa, 2015). Rapid technological change, global competition and shorter product life cycles have transformed companies' environments and forced them to look for partners for knowledge creation. Likewise, universities face the growing challenge of applying for funding and remaining leading experts in their subject areas in collaboration with companies (Ankrah and AL-Tabbaa, 2015).

According to Santoro and Betts (2002), two kinds of IU relationships exist. In a *sponsorship relationship*, companies provide researchers with resources and financing to solve specific problems or build basic knowledge with a long-time horizon. In a *partnership relationship*, interaction is ongoing, and companies consider universities as a source of basic knowledge or complementary expertise and resources, such as highly trained future employees (Santoro and Betts, 2002). Both IU relationships take time to develop (Pizam *et al.*, 2013), and development may even be prevented if faculty members lack industry experience, interest in working with companies or appreciation for the companies (Pizam *et al.*, 2013). IU relationships are usually formed as joint ventures, formal networks, consortia or alliances (Barringer and Harrison, 2000). There are three main benefits to these relationships:

(1) economic benefits to the overall economy;
(2) institutional benefits to the universities and the industry; and
(3) social benefits related to a communal activity or promoting sociability (Ankrah and AL-Tabbaa, 2015).

One major hindrance to innovation in construction is the lack of coordination between the industry and universities (Dulaimi *et al.*, 2002). Therefore, the focus should be on improving collaboration between the two to advance the process of implementing construction innovations (Xue *et al.*, 2014). Inter-organisational relationships are challenging to manage because of the actors' different needs (Barringer and Harrison, 2000). Hence, research suggests creating a shared vision for the actors, which guides the activities between them and can result in better business opportunities (Matinheikki *et al.*, 2017a).

Methodology

Design science research for developing an industry–university consortium relationship

The authors engaged in design science research from September 2016 to August 2019 to develop an IU consortium relationship that enables the creation of process innovations in construction and the conduct of scientific research on operations management in construction. Based on empirical data from this development act, a conceptual model for creating a win-win IU relationship that enables process innovations in construction through university research efforts was developed. The studied phenomenon took place in its real-life context, but it required changes to initiate the process. Design science research was chosen as the research approach because it allows researchers to design artefacts – such as methods, solution concepts or systems – which support "stakeholders engaged in construction management practices" (Voordijk and Adriaanse, 2016, p. 538).

Design science research creates functional, useful knowledge that practitioners can apply in daily practices (Van Aken and Romme, 2009). Design science research consists of two tasks: *building*, which is the process of developing an artefact for a specific purpose, and *evaluation*, which is the process of measuring how well the artefact works (Voordijk and Adriaanse, 2016). The design science approach provided the researchers with access to rich, in-depth empirical data and an opportunity to promote process innovations in construction.

During the analysis and reporting phase, the researchers analysed documents, including presentation materials from consortium meetings and steering group meeting minutes. Each university participant active in building the consortium wrote a narrative listing the development actions and their observed outcomes. These narratives and meeting materials were utilised to document how the various research efforts funded by the consortium were linked together and what were the essential steps for developing the consortium from 2016 to 2019.

Survey and interviews for measuring the impact of the consortium's research

To evaluate the academic impact of the research funded by the consortium, each principal investigator of a consortium-funded research project was asked to report the essential findings and activities as well as the number of conference papers, journal papers, master's theses and research reports published based on the results of the project. An online survey was conducted to evaluate the impact of research on individuals, companies and the construction sector. In other words, the researchers evaluated how well the developed artefact worked (Voordijk and Adriaanse, 2016) from industry participants' points of view. Another purpose of the survey was to understand how to develop the activities and management of the consortium. At the end of 2018, the survey was sent to 108 individuals (chief executive officers [CEOs], steering group members and group members) who had been involved with the activities of the consortium. The response rate was 28%. Most of the respondents represented group members (57%), but some steering group members (20%) and CEOs (17%) also responded to the survey. Other respondents represented subsidiaries of the consortium's companies; 60% of the respondents had been involved with the consortium since 2016, 33% since 2017 and the rest (7%) since 2018.

The survey measured the impact of each research project on individuals, companies and the sector. Also, five in-depth company interviews in spring of 2019 were conducted to understand more deeply the impact of the consortium on those companies. The interviews took place on April 11; May 14, 15 and 28; and June 25. The interviewees voluntarily signed up for an interview while filling out the questionnaire. The interviewees, who represented five different companies, included CEOs, steering group members and a regular group member. All the interviewees had been involved with the research activities of the consortium, and 60% of them had been involved with the consortium since its creation in 2016.

Data analysis

The researchers followed the logic of abductive scientific reasoning (Dubois and Gadde, 2002b) in interpretive design science research; thus, their understanding progressed as a continuous dialogue between the research data collected from 2016 to 2019 and existing theoretical knowledge (cf. Mantere and Ketokivi, 2013) on process innovations in construction and IU relationships. Insights that emerged from the research results affected the selection of the next year's research themes. The overall aim was to enable the conduct of both scientifically and empirically relevant research.

Findings

The development of an industry–university consortium relationship

In 2015, a newly appointed professor visited 40 Finnish design and construction companies to understand their current challenges and find IU collaboration possibilities. The companies were selected based on previous contacts from working with the industry and by contacting all the participants of building information modelling (BIM) conference held in Finland. The visits confirmed that the time was right for collaboration between multiple companies and the university. The companies were frustrated because one company alone could not implement process innovations; instead, multiple companies needed to change their ways of working at the same time. However, they were concerned that they would have to share company-specific short-term (up to 5 years) strategic goals with their competitors. Therefore, the collaboration was initially founded on the idea of long-term planning and creating a vision for the industry that goes beyond the strategy horizons of the participating companies. At the same time, the acute problems of today's practices could be addressed by finding a consensus between all parties.

It took six months to negotiate the rules of the consortium and gather the original group of 11 companies together. The consortium was created with two membership levels. The standard level allowed a company to participate in all meetings and workshops and to gain access to all materials and reports but did not include any decision power or company-specific work. The steering group level paid a higher annual fee, gained access to company-specific work by the researchers and participated in the steering group of the consortium. The steering group decided annually on the research topics based on proposals submitted by professor-level principal investigators. Because the researchers submitted proposals for consideration, all topics were relevant from the academic point of view and could result in scientific publications.

Between 2016 and 2019, the consortium conducted ten research projects with nine themes: a Vision 2030 for the construction sector; an international benchmarking study; trust in construction; lean design management; takt in production and design; mechanical, electrical and plumbing (MEP) prefabrication; a platform-based technology for trust-building; new logistics solutions; and measurement of waste. Table 1 summarises the research projects, key IU activities and consortium participants from 2016 to 2019. The

Time	Research projects	IU activities	Participants
September 2016 to August 2017	• International benchmarking study • Trust in construction • Lean design management • Vision 2030 for the construction sector (start of the project)	• 12 IU meetings where research results were presented and discussed • 2-day IU summer seminar • Researchers received 751 survey responses, conducted 26 interviews, visited 7 countries and 9 universities and attended 3 global conferences • An IU visit abroad (Norway, lean design management focus) • 3 conference papers published • 4 master's theses completed • 2 research reports	• 11 companies • 2 professors 1 post-doc 3 PhD students and 4 master thesis students
September 2017 to August 2018	• Vision 2030 for the construction sector (finish of the project) • Takt in production and design • Prefabrication of MEP[b] systems	• 18 IU meetings where research results were presented and discussed and ideas were further co-created • 4 journal papers published • 5 conference papers published • 3 research reports • 6 master's theses completed • Researchers conducted 2 takt case studies and 30 interviews, visited 5 countries and attended 2 conferences • An IU visit abroad (Germany, takt production focus) • Takt training and lean design management sessions	• 13 companies (~100 individuals) • 2 professors 1 post-doc 3 PhD students and 4 master's theses students
September 2018 to August 2019	• A platform-based technology for trust building • New logistics solutions • Impact of MEP prefabricated solutions • Measurement of waste in construction	• 14 IU meetings where research results were presented and discussed • 1 journal paper in review, 4 journal papers in preparation • 6 conference papers • 6 master's theses • 3 research reports • Presentations in stakeholder meetings	• 17 companies (~130 individuals) • 2 professors 1 post-doc 3 PhD students and 3 master's theses student

Notes: [a]IU, industry–university; [b]MEP, mechanical, electrical and plumbing

Table 1.
Research projects, IU[a] activities and participants

consortium's work was carried out in workgroups in which researchers and company representatives, often employees responsible for company development but also interested superintendents and project managers, would collaborate on the selected research topics.

September 2016 to August 2017. The research theme of the first project was driven by the need to understand best practices utilised abroad that could be implemented in the Finnish construction sector. The objective was to create a starting point for the Vision 2030 by assessing global state-of-the-art processes in this and other similar industries. The researchers set out to find processes and technologies that could shorten construction cycle times without adverse effects on quality, cost and safety. A benchmarking study was started with two global surveys, one related to current production planning methods and another to construction innovations. With 751 responses, these surveys led the research team to visit seven countries, including technical visits to nine universities and 25 companies. The findings of the benchmarking study were presented to the CEOs of participating companies in bi-monthly meetings and culminated in an industry report that identified 25 themes of interest where developments should be made. Two themes were chosen as the best candidates for future exploration because they had remarkably decreased cycle times in several of the studied markets. The first was prefabrication of MEP elements and the use of volumetric modules, and the second was the implementation of takt production. These findings eventually led to new research efforts on these topics in subsequent years.

The theme of the second research project was lean design management, which was driven by the practical observation that friction exists between the design and production processes, which creates challenges for project execution (Pikas *et al.*, 2020). The consortium companies were alarmed by the observed increase in litigation related to design management issues. As a research result, lean design management tools were defined, which several of the consortium companies have begun to implement in their work. Additionally, the design companies and construction companies now understand the business drivers of the other parties involved, and several fruitful collaborations have been created.

The theme of the third project was trust in construction (Uusitalo *et al.*, 2019). The aim was to identify practical solutions and methods to create and manage this trust. The research revealed that trust between actors is crucial in improving the quality and productivity of construction, and it requires management's attention in all project phases and even outside the project. Trust was defined as the belief that the other party will do what he/she promises.

September 2017 to August 2018. During the second year, a workgroup consisting of CEOs from the companies developed a vision for the construction industry for the year 2030 (Seppänen *et al.*, 2018). The researchers facilitated the vision development process using bottom-up and top-down approaches. Bottom-up ideas were collected by interviewing construction sector parties, whereas top-down ideas were created by reading already published studies on the future vision for the sector. The vision consisted of five themes:

(1) trustworthiness;

(2) buildings that are safe and support users' functions;

(3) sustainable development;

(4) productivity; and

(5) inspiring to people.

The companies have agreed to implement new practices that will lead to the accomplishment of the Vision 2030. The role of the vision is also to guide future research proposals submitted to the consortium.

Takt in production and design was chosen as the theme for the second research project (Lehtovaara *et al.*, 2019). The decision was based on the international benchmarking study conducted during the first year, which yielded takt production as one of the most promising new methods to radically reduce production durations without increasing costs or compromising quality. The goal of the project was to increase understanding of takt and its implementation possibilities in Finnish construction production and design operations. The obtained results were extremely positive. Regarding implementation, lead time was radically decreased in the production phases where takt was implemented, and this occurred without compromising costs or quality. The results received a fair amount of attention within the companies and in the Finnish media; a Finnish construction magazine wrote five stories on the takt production results (Mölsä, 2019). After the research project, several other companies within the consortium and some outside of it have reported implementation cases and concluded that takt production had a positive impact on their operations. However, the success would be further enhanced by removing critical bottlenecks in the process related to logistics. This observation led to the adoption of the logistics theme in the third year.

The third research project focused on understanding the barriers for implementing MEP prefabrication in Finnish construction projects (Lavikka *et al.*, 2018). The study considered MEP prefabrication as a systemic innovation and analysed the barriers, enablers, value addition, value capture and the design and construction process needed when implementing MEP prefabrication in Finnish construction projects. The study found social, political and economic barriers and enablers for implementing MEP prefabrication. The results showed that each party in the construction supply chain could benefit from MEP prefabrication, and its implementation necessitates that the main project parties – the client, designers, general contractor, MEP contractor and fabricator – adopt three new collaborative tasks in the prevailing construction process.

September 2018 to August 2019. The third year focused on increasing trustworthiness and productivity in construction, which were the first and fourth themes of the Vision 2030. To address the first theme, trustworthiness of the sector, the consortium collaborated with a third party to help in the development of a technological platform for trust building. An app to collect stakeholder feedback has now been developed, and it is currently being piloted in real construction projects.

The theme of the second research project was new logistics solutions (Tetik *et al.*, 2019). This research was initiated because most of the challenges in takt implementation case studies were related to logistics. A master's thesis was written on the application of logistics centres in a city centre. Also, the group studied vendor-managed inventories, just-in-time deliveries and kitting.

During the third year, the prefabrication research theme from the previous year was continued by developing a multi-criteria tool to evaluate the versatile impacts of prefabrication (Chauhan *et al.*, 2019). The research showed that the tool helps project stakeholders to communicate about multifaceted impacts of production methods and to make the final decision on whether to prefabricate or not.

The fourth research project measured waste in construction. The goal of the companies was to find ways to measure waste in real-time and understand the phenomenon better. One journal paper was published on the use of indoor positioning on the measurement of waste (Zhao *et al.*, 2019). It was found that workers spend only 30% of their work time in the work locations, which agrees with previous manual observations. Also, six master's theses were completed or are currently in progress related to various aspects of waste.

The impact of the industry–university consortium's research results

The IU consortium's research efforts have had both practical and scientific impacts. The survey results indicate a practical impact; research results have encouraged companies to implement new process practices and made them think about future changes in company operations. For example, 27% of respondents reported that they had implemented lean design management practices, while 20% of respondents reported that they had piloted takt production in their projects. The research conducted has encouraged companies to pilot new ideas:

> The research results have created faith that I am on the right track. I can refer to academic results when trying to convince others. We have piloted some of the ideas discussed in the consortium meetings (Respondent 1).

Another respondent stated that "We have piloted prefabricated products, but we still have lots to learn because the whole construction process needs to be changed" (Respondent 2). Finally, a third stated, "We implemented a takt production schedule on a site" (Respondent 3).

The research has also encouraged companies to develop new practices: "We made a specification that needs to be followed when designing prefabricated products" (Respondent 2). According to another respondent, "We are developing a new design process" (Respondent 4).

However, quantitative references would help in the selling of new ideas, as one manager explained: "It would be easier for me to sell the ideas if I had some euro references of benefits to back up my ideas" (Respondent 5). In addition to these pilots, the respondents reported a more optimistic atmosphere in their companies, for example, "We now have a more optimistic atmosphere towards changes" (Respondent 1). The respondents had seen some changes occur in the construction sector, but as one of the respondents described, "It is too early to ask for the changes in the construction sector since the consortium has been working for such a short period" (Respondent 3).

The knowledge of the consortium's existence and research efforts continues growing, and new companies are requesting to join. The participating companies have realised that the implementation of process innovations necessitates systemic changes in design and construction processes. In practice, systemic changes require buy-in and commitment from all involved project actors; otherwise, the ideas will not be implemented.

The interviews provided the researchers with a deeper understanding of the changes implemented in five different companies. The main finding was that the research conducted in the consortium has inspired and motivated company CEOs to pilot new operations management practices, such as takt production and lean design management. The interviewed company CEOs felt that the consortium had given them the courage to try new practices, as one CEO explained, "The consortium has functioned as background support for my thinking, as other companies are also looking at these new management practices, so I feel more confident in piloting them myself" (Respondent 6).

The CEOs also reported that the discussion between companies is important since collaboration starts with personal relationships between people. One interviewee mentioned that the business collaboration between the consortium companies is now more comfortable because the companies understand some key concepts in the same way because of collaborative discussions during consortium meetings. However, one interviewee thought that the consortium would need to continue the development of a shared vision for the future, as the current vision with its five themes is too broad and does not allow the Finnish construction sector to stand out from other countries. As an example, the interviewee mentioned that Finland once was a leading country in the development of BIM technology.

According to another interviewee, the sector is very conservative and not willing to implement new practices, but the collaborative discussion in the consortium has enabled members to agree on new process practices that need to be implemented. The interviewee also stated that having a professor visit their company and provide help was vital to implementing the practices. For example, the instructor provided training sessions on takt and lean design management and gave several presentations in stakeholder meetings where customers of the consortium companies were present.

The consortium's research efforts have also had a scientific impact. Thus far, researchers have published four journal articles in leading construction management journals. Additionally, one journal paper is in review and four others are in preparation. In addition to journal articles, the researchers have published eight publicly available research reports, 15 conference papers and 13 master's theses. The research efforts contributed to several doctoral theses by providing the candidates with rich empirical data.

A conceptual model for creating a win-win industry–university innovation relationship

The survey and interview findings confirm the practical usefulness of the consortium's research. For example, successfully implemented takt production indicates that process innovations can be introduced to the construction sector through the developed IU consortium. Further, the scientific results published thus far provide evidence that long-term IU collaboration can be regarded as a method for conducting research that is also scientifically relevant. Based on these findings and the development process of creating the IU consortium, we developed a conceptual model for creating a win-win IU innovation relationship (Figure 1).

The model is a combination of the two IU relationships defined by Santoro and Betts (2002). The consortium companies have provided researchers with resources and financing to study specific problems. This approach is similar to the *sponsorship relationship*, but the researchers are not required to solve problems but merely provide suggestions based on the research data and observations. The model also shares some similarities with the *partnership relationship* in which interaction is ongoing, and companies consider universities as a source of complementary expertise and future employees.

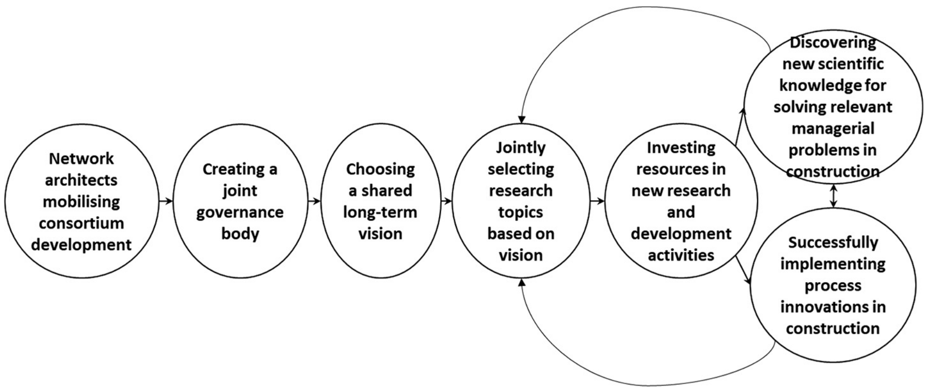

Figure 1.
A conceptual model for creating a win-win IU innovation relationship

The model consists of six steps, and their interdependencies are shown in Figure 1. The first step is *network architects mobilising consortium development*. Balanced roles are needed between the university actor and leading industry actor to mobilise new actors joining the consortium, forming a shared vision for it and setting rules for collaboration. In the beginning, the role of the network architect was given to the professor who had recognised an opportunity for implementing process innovations through an IU consortium. A consortium company CEO volunteered to be the chairman of the CEO group, which motivated other companies to join the consortium. Academics are considered as neutral players and thus suitable actors for orchestrating innovation systems (Gastaldi *et al.*, 2015). The recognition of an opportunity for implementing process innovations is similar to the innovation development process created by Blayse and Manley (2004), who stated that the first step is to recognise an opportunity for innovation.

The second step in the model is *creating a joint governance body*, which in the consortium is a steering group that consists of core members who select new research topics and accept new members on an annual basis. The joint governance body is linked to the second step of Blayse and Manley's (2004) innovation development process, creating the climate for innovation. An active steering group has been crucial in creating a climate of trust between the companies. The active steering group confirms Shapira and Rosenfeld's (2011) statement that construction companies look for innovative ideas, despite the sector being criticised for its conservatism. The steering group created the rules for collaboration, and it approves any new consortium members.

The third step, *choosing a shared long-term vision*, provides an agreed-upon understanding of challenges and opportunities in the sector and has helped facilitate collaboration between the companies. A shared vision was created through a dialogue about challenges, megatrends and benchmarks. A vision must extend beyond the companies' current strategic period and represent something that each actor perceives as crucial to themselves. It can be argued that this element is also connected to the second step of Blayse and Manley's (2004) innovation development process, creating the climate for innovation. The shared vision provided the boundaries for selecting new research topics, which have led to new process innovations. Research has also shown that a shared vision can result in better business opportunities, thus implying that the communication of a shared vision is an important element of an IU relationship (Matinheikki *et al.*, 2017b; Matinheikki *et al.*, 2017a).

The fourth step is *jointly selecting research topics connected through reflection between annual research cycles*. New research topics need to be jointly selected by the university and companies on an annual basis. The selection of research topics is based on coherence, continuation and democracy. New research topics need to connect with the shared vision and unsolved and emerging issues found in previous years' research.

A good IU collaboration necessitates that both parties can cherish their own goals, as discussed by Champness (2000), as well as the mutual goal of developing the construction sector. The companies must create capabilities that allow them to survive in the long term, whereas universities are dependent on interesting, well-conducted scientific research and high-quality teaching that enables them to attract competitive funding and talented students. However, a good IU relationship does not take place without coordination efforts, as described by Dulaimi *et al.* (2002). They suggested that researchers are in the key position to understand what kind of research would benefit both parties. Researchers, as facilitators of collaboration, should suggest research themes that can potentially lead to breakthrough findings and also benefit companies in the long-term.

The fifth step is *investing resources in new research and development activities*. The consortium members must commit to investing financial and personnel resources in research projects and implementing findings in pilot projects for a long-term period (Aouad *et al.*, 2010). High commitment is one of the prerequisites for successful innovation implementation (Dulaimi *et al.*, 2003). This step is connected to the third step of Blayse and Manley's (2004) innovation development process, providing new construction technology. The last step, *assessing scientific and practical impact through a systematic process for managing research projects*, is only possible through long-term commitment. The new scientific knowledge may be related to the development of new processes and management models (tested through empirical studies) or may be combinations of existing models and concepts. The successful implementation of new operations management practices (i.e. process innovations) is firm and network-level outcomes. This step is linked to the final step of Blayse and Manley's (2004) model, in which new practices are experimented with and finally implemented. Table 2 summarises the steps for creating an IU innovation relationship and provides empirical evidence for its advantages for academics and practitioners.

At its best, a well-functioning IU relationship serves the three purposes of the university: research, teaching and societal impact (Champness, 2000; Ankrah and AL-Tabbaa, 2015). Thus far, the consortium relationship developed in this study has met these three needs. It has allowed the researchers access to current practices as well as the implementation of new practices in companies. Professors have taught the research results gained in the consortium to university students, and the companies have been willing to provide industry-perspective lectures and host student visits to their real-life projects. Finally, by facilitating the implementation of the process innovations, the researchers have made a societal impact.

The companies must now implement the research results. The university researchers cannot take responsibility for implementing the research results in company practices, but they can suggest approaches and processes for implementation and leverage research findings. In the best scenario, the university can provide the companies with an environment conducive to implementing process innovations and practitioner researchers who are capable of working with academic research in the context of construction, as discussed by Gann (2001).

There are, however, some challenges with the IU consortium model. At the moment, client organisations are missing from the consortium, as current members are designers, contractors and software companies. This is because the consortium's research efforts thus far have focused on production planning and control, whereas clients are usually more concerned about the quality of the end result. Clients are, however, an essential ingredient in construction innovation (Aouad *et al.*, 2010), and thus, their voices need to be heard during the implementation of process innovations.

Another challenge with the consortium is that the developed Vision 2030 includes too many topics, which complicates the focus of future research efforts. Research has suggested that innovation systems always need a clear goal that guides the activities of the participants (Woiceshyn and Eriksson, 2014). A third challenge for the future is that research efforts have been dependent on the professors' research interests. However, companies could suggest topics outside of the professors' expertise. The consortium also needs to decide how big it can grow (i.e. how many new members it will accept) without compromising the coherence of the members.

Conclusions

This study adds to the discussion on the rigour and relevance of construction management research (Bresnen, 2017; Ivory, 2017; Koskela, 2017) by presenting a conceptual model for creating a win-win IU relationship that enables the conduct of

Table 2. The steps taken to create the IU[a] innovation consortium

Process step	Description	Advantage for academics	Advantage for practitioners	Evidence from the empirical study
Network architects mobilising consortium development	Roles were balanced between a university actor and a leading industry actor to mobilise new actors joining the consortium and setting rules for collaboration	A professor-level principal investigator proposed research topics that would potentially lead to new scientific knowledge in operations management in construction	A professor with a strong background in operations management in construction was considered an objective third party with relevant practical knowledge to guide the mobilisation of the consortium	A professor visited several companies to find those willing to develop the sector in collaboration with other companies. He also facilitated the negotiation of rules for the consortium, which was crucial for reducing the fear of unintentionally sharing company-specific short-term strategic goals to competitors
Creating a joint governance body	A steering group was created consisting of core members to select new research projects, follow the execution of projects (time, cost, quality), and accept new members A CEO[b] group was created to make the consortium relevant at the industry level	The steering group made sure that companies committed to selected research topics, thus providing necessary resources for research activities The CEO group enabled researchers with access to multiple perspectives on focused managerial problems, which helped in formulating and validating artefacts and conceptual models	The steering group made sure that researchers conducted practically relevant research and that consortium members were committed to changing practices in the sector The discussions among the CEO group and researchers contributed to understanding of phenomena from multiple perspectives and enabled the creation of a shared vision that every member perceived as beneficial, thus creating a basis for systemic innovations	The steering group met three times a year to select new members based on their willingness to change the practices in the sector The consortium consisted of both competing and complementing companies in the same sector, including general contractors, designers, engineering and consulting offices, building product companies, software companies and specialised contractors. Access was open for new members to join the consortium. The group also selected research projects

(*continued*)

Table 2.

Process step	Description	Advantage for academics	Advantage for practitioners	Evidence from the empirical study
Choosing a shared long-term vision	A long-term, shared vision provided a shared understanding of challenges and opportunities in the sector. The vision was considered crucial by each actor	The shared vision enabled companies' headquarter-level commitment to the research and implementation, thus providing the researchers with easy access to empirical data	The shared vision extended beyond the companies' current strategic period, thus ensuring collaboration instead of competition in the consortium	The CEO group, together with the researchers, created a long-term shared Vision 2030 for the construction sector to glue the companies together. The vision creation entailed a dialogue about the challenges, megatrends and benchmarks of best practices and opportunities
Jointly selecting research topics connected through reflection between annual research cycles	New research topics were jointly selected based on the need to connect with the shared vision and address unsolved and emerging issues found in previous years' research. After each year, reflection on project results was used to guide decision making about new projects. There were two options to create connections between the topics: deepening the topic to the identified unsolved area or extending the topic in a new relevant direction	Continuation in research topics enabled PhD students and post-docs to deepen their expertise in the selected initial topic and widen it to the practically relevant area	Research was directed to relevant areas for practitioners so that new models created in the first year could be implemented in the second year	The steering group discussed and voted for research topics yearly. The selection of research topics was based on coherence, continuation and democracy. Based on the first year's benchmarking study, new projects about prefabrication and takt in design and production were launched. The prefabrication theme was deepened during the third year to focus more on the topics of implementation and evaluation. The research was extended to logistics, which is a topic identified based on the requirements for takt in production

(*continued*)

Table 2.

Process step	Description	Advantage for academics	Advantage for practitioners	Evidence from the empirical study
Investing resources in new research and development activities	Consortium members made long-term commitments to provide financial and personnel resources for research projects and to implement findings in pilot projects. The companies signed an ongoing consortium contract with the university with no predefined ending time	Researchers have a better outlook about future funding as well as incentives for conducting long-term research	Practitioners can familiarise themselves with the research group, decrease administrative bureaucracy and redirect research activities inside a funding vehicle instead of launching a new funding arrangement	All first phase members have remained in the consortium, and three of them have upgraded their status to the steering group level
Assessing scientific and practical impact through a systematic process for managing research projects	New scientific knowledge on solving relevant managerial problems has been discovered, and new operations and management practices have been successfully implemented	Each research project has lasted one year, had similar meetings structure (four to five per year) and created deliverables, which were relevant for both the practitioners and the researchers	Standard project process and timing has motivated practitioners to participate in projects, provide researchers with access to empirical data and prepare for the early implementation of results	New processes and management models were developed and tested with empirical studies; new knowledge on combinations of existing models and concepts was developed. The CEO group has provided the researchers with access to relevant construction sites. Some CEOs have written publicly about the research conducted and their companies' commitment to executing research results

Notes: [a]IU, industry—university; [b]CEO, chief executive officer academic research and creation of process innovations in construction. Other universities that aim to conduct both practically and scientifically relevant research in the field of operations management in construction can apply this model. The model is based on an empirical study using a design science research approach in an inter-organisational context.

The limitation of the study is that it does not test and compare the developed model with other similar models worldwide (Shapira and Rosenfeld, 2011). Further research endeavours should focus on understanding whether the specific context of the Finnish innovation system (cf. Woiceshyn and Eriksson, 2014) contributes to the success of the developed IU consortium relationship or whether the model could also work in IU relationships abroad.

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