COORDINATING INNOVATION IN DIGITAL INFRASTRUCTURE: THE CASE OF TRANSFORMING OFFSHORE PROJECT DELIVERY

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Abstract. The relationship between digitalization, digital innovation, and digital transformation is an emerging topic in information systems (IS) research. Whereas IS researchers widely acknowledge that digitalization underpins both digital innovation and digital transformation, just how and by what mechanisms link digital innovation with digital transformation remains underexplored. Differentiating between 'digital infrastructure innovation' and 'innovation in digital infrastructure', this paper contributes towards current discussions by empirically elaborating how the open-ended and generative potential of digital innovation in practice has to be negotiated against the installed base of technical and organizational arrangements in digital transformation. We pursue this argument through a case study of digital innovation coordination in an inter-organizational digital innovation project with the goal of instigating digital transformation within the offshore construction industry.

Keywords: Digital Innovation, Digital Infrastructure, Digital Transformation, Digital Delivery.

1 Introduction

Digitalization[1] impacts on central aspects of industrialized society, ranging from the reshaping of individual organizations to the transformation of entire societal sectors and industries. At the same time, digitalization transform the very character of innovation as the open-ended and generative capacity of digital technologies challenge fundamental assumptions about innovation boundaries, agency, and the process-product relationship [1]. While Information Systems (IS) researchers widely acknowledge the relationship between digital innovation and the transformative im-

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[1] Drawing upon Tilson et al. (2010) we understand digitalization as the socio-technical processes through which digital technologies become infrastructural to work and organizing

pacts of digitalization, just how and by what mechanisms the two are linked remains an issue of much debate among IS researchers [2-6].

In this paper, we contribute towards these discussions through a case study of digital innovation for transforming project delivery in the offshore construction industry. Through this case study, we empirically elaborate how the open-ended and generative potential of digital innovation in practice has to be negotiated against the installed base of technical and organizational arrangements in digital industrial transformation. This argument supplements ongoing discussions about the open-ended possibilities of digital technologies in IS research [e.g. 2] by emphasizing how digital innovation unfolds within the confines of existing industrial, organizational, and technological structures. To this end, we empirically demonstrate that digital innovation network dynamics emerge through the interplay between generativity and installed base.

We pursue our argument through an analysis of digital innovation in the Open Industry Platform (OIP, pseudonym for maintaining anonymity), an industry-level collaboration project in the offshore construction industry. Specifically, we follow the challenges OIP faces in transitioning from a stage of mobilizing industry support for the project towards a full-scale digital innovation project. Emphasizing how digital innovation is negotiated towards an installed base of existing sociotechnical arrangements, this paper can be regarded as a response to Nambisan [5] call for more research on institutionalized aspects (i.e. installed base) of digital innovation. More specifically, this paper contributes to theory on digital innovation networks in three ways. First, we empirically demonstrate and draw implications of a temporal, evolutionary dimension to digital innovation networks. Second, we elaborate upon and substantiate the need for coordinating mechanisms to evolve as digital innovation networks change. Third, by arguing for the embeddedness of digital innovation networks in other network structures and its implications for digital innovation. We also draw practical implications for coordinating large-scale and complex digital innovation projects.

2 Digital innovation coordination and digital infrastructure

While digital innovation is by now a well-established topic in IS research [1, 7], IS researchers approach it somewhat differently. On the one hand, there are those who emphasize digital innovation as processes, products, or business models that are new and enabled by IT [e.g. 7]. This paper, however, draws upon a recombination approach to digital innovation [8]. Emphasizing digital innovation as producing novel products through new combinations of digital and physical components, this approach emphasizes digital technologies' generative and open-ended potential enabled through the key characteristics of being editable, re-programmable, and with functionality that can be procrastinated until the point of use [2]. This differentiates digital innovation from earlier forms of IS innovation [9] by two distinguishing features: the changing role of digital technology in innovation from operand to operant resources, and a shift in innovation locus from firm-centric to innovation networks.

Pervasive digitization changes the role of digital technologies from an enabler for innovation (operand resource) to a trigger for innovation and medium through which innovation unfolds (operant resource) [10]. Digital technologies as operant resource conflates innovation product with process [10], with attention shifting towards reconfiguration [8] of innovation processes and the generativity unleashed by digital resources. Pervasive digitalization also shifts innovation locus from firm-centric to innovation networks. Innovation no longer unfolds within a single company, but through a network of actors [13].

Digital innovation affords, as such, new modes of coordination. Based on the two distinguishing characteristics of digital innovation, Lyytinen, et al. [3] forward a framework for innovation network coordination that characterizes innovation networks along the two axes of 1) heterogeneity of operant resources, and 2) distribution of coordination and control within the innovation network structure. Through this framework, they forward that there is limited need for social and cognitive translation when innovation networks consist of “a homogenous pool of actors and related tools that are readily identified” (ibid., p.58). Lyytinen et al. define cognitive translate as “a generative process whey innovation knowledge is identified, produced, refined, integrated and evaluated partially through digital means in its movement towards (…) being stabilized in a new product” (p.55), and social translation as the processes through which “an innovation process, by necessity transforms the social space of the actors in the innovation network” (p.56). As such, in networks of actors consists of heterogenous operant resources, coordination mechanisms’ need to support social and cognitive translation. Specifically relevant to this paper is what Lyytinen, et al. [3] characterizes as ‘anarchic’ digital innovation networks; i.e. networks with operant resource heterogeneity and distributed control and coordination as ‘anarchic’. These networks are characterized by collaboration of self-adjusting actor-to-actor networks driven by opportunistic behavior with “actors spontaneously sensing and responding to their continued market relevance and viability/sustainability” [12].

Digital infrastructures offer a pertinent example of anarchic innovation networks. Digital infrastructures underlie pervasive digitalization of organizational life [13]. Drawing upon a network perspective on infrastructure [cf. 14], Tilson, et al. [13] characterized digital infrastructure as “shared, unbounded, heterogeneous, open, and evolving sociotechnical systems comprising an installed base of infrastructure capabilities and their user, operations, and design communities”. Digital infrastructure innovation is, as such, subjected to heterogeneous and distributed actors’ independent choices beyond the control of any central actor [15]. A key challenge is, as such, handling the different interests. However, as Sørensen [15] notes, specific control mechanisms are needed to coordinate and balance distributed action for digital infrastructure innovation to be successful.

While there is some research on coordination in networks of heterogeneous operant resources and distributed control and coordination, Lyytinen, et al. [3] argued that the main challenge in digital infrastructure innovation is to actualize digital innovation in such networks. The degree of alignment between network actors is a particular challenge pertinent to this paper. Swanson and Ramiller [16] forwards the notion of ‘organizing vision’ to explain the productive capacity industry buzzwords have in mobilizing and shaping actors' expectations and opportunities in innovative application of digital technologies. Similarly, Pollock and Williams [17] shows how industry analysts' classifications of different digital technologies influence the trajectories of emerging classes of digital technologies. While both studies show coordination across heterogeneous networks, they do so among loosely aligned actors. While some mechanisms function in loosely aligned networks (such as organizing visions), other mechanisms are needed as networks become more closely integrated and aligned; as in digital infrastructure innovation. Furthermore, while IS scholars acknowledge the importance of digital innovation coordination, Nambisan [5] argues there is still lack of knowledge about institutionalized aspects of innovation. In the case of digital infrastructure innovation, such institutional aspects include the installed base of organizational, technical, and financial investments [18]. As such, digital innovation coordination needs to encompass the tension between the generativity and open-ended potential of digital innovation [2] with the digital infrastructure's installed base.

3 Methods and materials

This paper draws upon the authors' engagement with digitalization of offshore construction projects over the past three years. The empirical data are mainly from the first author's embedded case study [19] of OIP (project title along with company names have been anonymized). OIP is a collaborative project among companies throughout the offshore infrastructure industry. The project aims at developing an industry-wide system for digital exchange of technical information in offshore construction projects.

Participant observation [20] has been the first author's main data collection method for the case study. The author has been embedded with an OIP project team located at HostCo, the company responsible for project management of the joint project, from November 2018 through April 2019. During this period, the author spent 3-4 full days a week at HostCo, for a total of 54 days of participant observation. The author was provided with office space together with the project team and OIP management, with full access to observing meetings, spending time talking with the project team and management, as well as contributing by maintaining the project's document repository. Data from observations have been written in a field notes journal [21].

The first authors' participant observation has been supplemented with both authors' interviews and analysis of documents related to the project and the overall transition towards digital delivery of offshore construction projects. We have individually and together done 24 semi-structured interviews [22] with OIP's project participants including software engineers, domain experts, management-level participants and the project initiators.

We have conducted data analysis and collection in parallel. Initial data analysis was informal, aimed at narratively analyzing observations and interviews to form an overall understanding of the project. Over time, data analysis turned more systematic through coding of interview transcripts and fieldnotes for concepts and topics. During this process, we supplement the emerging analysis by sampling from the second authors' fieldnotes from participating in meetings and workshops related to digitalization of offshore construction projects at the industry level. Throughout this process, we sought to relate aspects of the emerging analysis back to different potential theoretical venues. In this paper, we draw upon literature on digital innovation networks and mechanisms for coordinating these.

4 Case setting: Digital offshore project delivery

The Open Industry Platform project sought to establish a system for digital exchange of technical information shared by all companies throughout the Engineering, Procurement, and Construction (EPC) industry. The EPC industry delivers offshore infrastructures such as pipelines, new production facilities, and more recently offshore windmill parks through large and complex infrastructure projects. The main contractor (usually referred to as 'the EPC company') subcontracts and outsources much of the project activities through a heterogeneous ecology of subcontractors, vendors, and service companies with different specialties. OIP was, to this end, organized as a collaborative project between key companies representing different stakeholders in this ecology.

Digital delivery is considered the next step of digitalization in the EPC industry. While practically every individual company have digitalized their activities, digital delivery is "the use of integrated software and processes across the project ecology" [23]. Technical information is the basis towards which companies in EPC projects verifies that individual pieces of equipment fulfil technical and regulatory requirements. Furthermore, forwarding the project as the transition 'from document-centric to data-centric' exchange of technical information, the initiators projected how OIP would not merely replace existing work processes. Seeking to mobilize industry support for the project during the first six months of 2018, OIP's initiators forwarded the project as the missing piece in transitioning towards digital delivery of EPC projects:

- What we are doing is a game changer, and can make tremendous changes to how we are working in large [offshore] construction projects (…) (OIP project participant, fieldnote excerpt)

However, upon project initiation in mid-2018, HostCo – the service company given responsibility for hosting and managing OIP – quickly faced problems. Reflecting upon this a few months into the project, a key project participant observed:

> "So, I now see that the project has been somewhat oversold in that the foundations of the project is more based on, let's say, hopes and aspirations rather than being expressions of a clear plan [of project goals and how to achieve them]." (Interview excerpt)

Labelling the initial months of the project a 'preparatory phase' prior to commencing the project proper in early 2019, HostCo worked to operationalize 'hopes and aspiration' through which the project initiators had sought to mobilize support for the project.

To facilitate a transition to digital exchange of technical information, OIP was to consolidate, update, and digitize existing standards that specify the informational elements required for different classes of equipment used on offshore installations. There is currently no single standard that completely specifies what information should be supplied for different equipment classes. Rather, they are distributed across over 50 different national and international standards (as well as company-specific documents). With little or no coordination among different standardization bodies, the standards are often overlapping and sometimes even downright contradictory. To this end, OIP was organized around two related activities at project initiation:

One activity was to update existing national guidelines by consolidating existing standards on technical information required of different classes of equipment

The other activity was to develop a core technology (OIP Core) for digitally expressing the requirements laid down in the updated national guidelines

The content of these activities, however, remained underspecified. As such, moving from 'hopes and aspirations' towards concrete project outcomes and activities turned problematic. OIP's participants spent most of 2018 seeking to operationalize the project vision into concrete technical features, and a plan laying out what activities are to be done by whom, when, and how. With this came a shift in focus for the activity to develop OIP Core. More than developing technology in support of digitizing the updated national standards, they came to focus on methods for expressing and processing digital requirements in general. Throughout this period, participants involved in updating the national standard repeatedly raised questions about OIP's functional focus, and the appropriateness of OIP Core's general requirements handling features for their activities on updating national guidelines for technical information and what they perceived as a lack of progress in this activity.

As such, how OIP's vision was to be operationalized into activities and materialized into concrete outcomes (plans, reports, revised standard, designs, executing software) remained contested as HostCo prepared to scale up the project for the second phase; the project proper. Consequently, when it came to mobilizing funding for the project proper in early 2019, most of the participating companies were hesitant. Several expressed the view that OIP was lacking a clear direction to meet the needs of the industry. As a key stakeholder put it:

– Isn't it discouraging that we have conducted a first [preparatory] phase of the project and no-one really knows what the outcome of this has been or how to progress from here? (Fieldnote excerpt)

As the preparatory phase came to a conclusion, several of the key companies involved in the project openly considered pulling out OIP, possibly even terminating the project entirely.

5 Analysis: Digital infrastructure innovation vs. innovation in digital infrastructure

Conflicting views on the nature of digital innovation in OIP lie at the core of the controversy threatening OIP's continuation after the preparatory phase. Echoing Schumpeter, Henfridsson, et al. [2] forward that "[r]ecombination is at the heart of innovation" (p.89). Rather than conceiving of digital technologies as pre-packaged applications or services, Henfridsson et al. (ibid., p.90) forward the notion of digital resources, "entities that serve as building blocks in the creation and capture of value from information". The technical approach chosen for OIP, which all participants agreed upon, followed a similar logic. Rather than developing a self-contained application, OIP was to provide a digital resource – the OIP Core – that its participants could freely integrate with their own technical and organizational arrangements. While agreeing on this, whether OIP Core would form the basis of a new infrastructure for digital EPC project delivery or simply provide functionality to be inserted in existing technical and organizational arrangements remained contested throughout the project period.

We conceptualize this as an unresolved tension between divergent views on the nature of digital innovation in OIP; between an emphasis on digital infrastructure innovation versus an emphasis on innovation in digital infrastructure. We draw the line of demarcation between the software engineers developing OIP Core, on the one hand, and the domain experts tasked with updating national guidelines on informational requirements for different classes of equipment on the other. Emphasizing the open-ended, transformative, and generative potential for a large-scale transition from document-based to data-oriented requirements handling, the software engineers regarded OIP as digital infrastructure innovation. The domain experts emphasized the need for OIP Core to take into account operators' and EPC companies' installed base of financial, technical, and organizational investments in digital EPC project delivery in general, and digital exchange of technical information in particular. As such, they viewed OIP as a form of innovation in digital infrastructure.

Table 1. Digital infrastructure innovation vs. innovation in digital infrastructure.

	Digital infrastructure innovation	Innovation in digital infrastructure
Description / Innovation dimension	Innovation of the infrastructure for digital EPC project delivery through OIP	OIP as an innovative part of existing technical and organizational arrangements for digital EPC project delivery
Focus	Technology-driven	Use-oriented
Trajectory	Start afresh with new technology	Build on existing activities
Outcome	OIP as digital platform outside of installed base	OIP integrated as system for digital exchange of technical information within installed base

5.1 Innovation focus

Organized around two related activities, OIP faced two possible points of departure at project initiation: 1) focus on updating national guidelines for technical information, or 2) focus developing a technology for expressing the requirements laid down in the updated national guidelines. There were discussions from onset of the project about which of these two activities to consider as driver of project activities. The software engineers working on OIP Core advocated that developing the technological basis of the project should be central to proceeding with updating the national guidelines. Although the domain experts agreed that the updated national guidelines should be digitized from the onset, their view on OIP Core's role in the project diverged from that of the software engineers:

- The goal is to update the standards [national guidelines for technical information]. The technology [OIP Core] is to support this process, rather than setting the premises for the standardization. (Fieldnote excerpt, OIP initiator)

At the onset of the preparatory phase, HostCo donated the results from a company-internal project for digitally expressing requirements on a machine-readable form. Their argument was that building on this as the technological basis for OIP would give the project a 'flying start'. The donated technology, which became OIP Core, was a technology for digital requirements handling in general. This aligned well with HostCo's other business areas in requirements validation and verification:

> "We [HostCo] are working with requirement in very broad scale and large volume. Much of what we are doing is about creating rules and publishing guidelines where most of them are based on industry standards. The complexity in understanding set of rules is work intensive. (....) It [OIP Core] will provide computer assistant requirement management by which we can move the burden of knowing and applying complex rules to the computer and then improve quality." (Interview excerpt, software engineer)

Deciding to use HostCo's general digital requirement technology for OIP Core emphasized requirements handling and its transformative potential on digital EPC project delivery. While the technology provided the domain experts with a format for unambiguously expressing requirements, they remained uninterested as their focus was on how digital technologies could simplify time-consuming and error-prone aspects of their work. As such, within the first months of OIP, the disagreement on project driver came to be drawn between the software engineers seeking to establish development of OIP Core, on the one hand, and the domain experts wanting technological development to be driven by the user needs for updating the national standards, on the other hand.

The software engineers attributed the domain experts' skepticism of digital requirements handling in general as a failure to grasp OIP Core's generative potential.

As such, they translated the domain experts' objections to OIP Core's emphasis on digital requirements handling as a form of user resistance. As a software engineer noted:

> "I have been in the oil and gas industry for many years myself, and I know that this is an extraordinary conservative business. Engineering and engineers by themselves are particularly conservative and procedurally oriented, right? And used to doing things the way they have always done." (Interview excerpt)

From the domain experts' point of view, however, software engineers failed to grasp OIP's role in the wider context of transitioning towards digital EPC project delivery:

> "We were introduced to an application which [the software engineers] believe is the best solution. But as we moved on, we understood this was only a small piece of the bigger picture. This is the drawback of [HostCo] having the potential solution in-house." (Interview excerpt, domain expert)

The domain experts attributed the focus on digital requirements handling to a lack of domain knowledge among the software engineers. The operators' domain experts argued the software engineer's insistence on digital requirements handling's generative potential failed to appreciate that the recipient and end-user for the technical information generated during an EPC project are the operators' life-cycle information departments[2].

> "The emphasis kind of changed towards the HostCo technology rather than focusing on the technical [information] requirements. I think they gave too much focus on that (…). In a way the work was done on the technology [OIP Core], it is kind of difficult to understand how that would work before agreeing upon what we want to digitalize and used that engine for." (Interview excerpt, management-level stakeholder operator)

Similarly, the EPC companies' domain experts argued that focusing on digital requirements handling failed to acknowledge key competitive dynamics in EPC projects. While technical information is the basis for validating that delivered equipment fulfils technical requirements, requirements validation efficiency is a key competitive factor among companies in the EPC ecosystem. All companies therefore have internal systems for requirements validation already. Moving such functionality to the digital infrastructure would undermine these companies' organizational and technological investments in requirements validation efficiency. As such, the disagreement over OIP Core's functional scope was not solely about functionality per se, but also on whether OIP's focus should be on digital infrastructure innovation or innovation in digital infrastructure.

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[2] Life-cycle information departments are responsible for providing technical information to internal departments as well as subcontractors in relation to operations and maintenance activities

5.2 Innovation trajectory

OIP is infrastructural in ambition and scope. The offshore industry's interest organization clearly signals OIP's infrastructural ambitions by concluding their report on future competitiveness with

"Digitalization: collaboration, sharing, openness, standardization. OIP is the foundation."

This statement reflects what Star and Ruhleder [24] refers to as the 'common-sense view' of infrastructure as "substrate (…) something upon which something else 'runs' or 'operates'". The conclusion forwards the ambition of OIP as the substrate for "collaboration, sharing" to underpin digital EPC project delivery. OIP is infrastructural in scope in its focus on cross-domain standardization. Henfridsson and Bygstad [14] describes a relational perspective on infrastructures. This perspective emphasizes infrastructures as socially embedded and coordinated across social worlds and standards. Companies throughout the EPC industry tend to spend an inordinate amount of time sifting through technical equipment information. Different suppliers provide the information on differing formats and with differing information depending upon the customer. In worst case, the same supplier can provide the same customer with differing information for the same piece of equipment as operators have limited standardization of technical information across their development projects. OIP is, as such, infrastructural in scope as standardizing the information elements to be provided for specific classes of equipment is key to coordinating across the different social worlds involved in EPC projects.

Both of these perspectives of OIP's infrastructural aspects are well acknowledged among the participating companies, and link closely with the view of OIP as digital infrastructure innovation; the innovation of the infrastructure for digital EPC project delivery. Less acknowledged, however, is how OIP is also innovation in digital infrastructure.

OIP had been preceded by a series of smaller, independent, yet related collaborative projects focusing on different aspects of digital exchange of technical information. Companies have, in the past, pursued digital EPC project delivery internally. The effect has been that vendors, subcontractors, and EPC companies spend much effort on transferring data and information to and from different companies' digital delivery systems. Key stakeholders throughout the EPC industry (including OIP's initiators) have therefore sought to consolidate and move internal systems onto what they referred to as 'the common arena' over the past years. All participating companies, apart from HostCo, have previous investments in at least some of these projects. In mobilizing participants for OIP, the project initiators therefore highlighted the importance of OIP as a continuation and consolidation of these past projects. The domain experts' objections to OIP Core's emphasis on digital requirements handling, can be understood as a failure by the software engineers to acknowledge that OIP is not developed in isolation, but within an installed base of financial, technological, and organizational investments [18] made by companies throughout the EPC ecosystem.

The domain experts' objections to OIP Core's emphasis on digital requirements handling was, as such, not solely a critique of the software engineers' lack of domain knowledge. They also found the focus on digital requirements handling to lack an appreciation of the need for continuity with previous industry efforts towards establishing an infrastructure for digital exchange of technical information in EPC projects:

> "I have participated in [a previous project on identifying informational element requirements for technical information] from 2015 to 2018 on behalf of my company. (…) From our side, (…) the OIP project is to use the results from previous initiatives. How can we say that the [previous] project is OIP's background without continuing it?" (Interview excerpt, domain expert)

Having attributed the domain experts' objections to a lack of understanding of digital requirements handling's transformative potential, the software engineers responded to the critique by organizing a workshop. The goal of this workshop was to instill an understanding of digital requirements handling's transformative potential among the domain experts by explaining the technical basis of OIP Core. Yet, as a management-level participant noted in the aftermath of the workshop:

– It isn't that the domain experts don't understand OIP Core. It's that they fail to see how it builds on and extends their existing work on identifying and standardizing the information elements' requirements for [different classes of] equipment. (Fieldnote excerpt)

Emphasizing the generative potential of digital requirements handling, the software engineers failed to acknowledge the other participants' previous investments in digital exchange of technical requirements. Indeed, by translating the other participants' objections to OIP Core's focus on digital requirements handling as a form of user resistance (as elaborated in 5.1 above), the software engineers failed to acknowledge that the other companies have previous financial, technological, and organizational investments in the digital exchange of technical information that they seek to further through OIP. Unresolved, the conflicting views of digital innovation escalated into suspicions over HostCo's ulterior motives to use OIP Core to re-configure the digital EPC ecosystem around their product offerings.

5.3 Innovation outcome

The EPC industry draws upon a wide array disparate, frequently overlapping, and to a certain degree even redundant digital systems for creating, exchanging, and storing information in a single infrastructure project or for an installation. The degree to which companies in the EPC industry implement digital delivery varies greatly. Most energy companies have their own internal systems for digital project delivery that all subcontracted companies are required to use. Similarly, all EPC companies have their own systems for digital delivery that their subcontractors and vendors are required to use. Even the large equipment vendors have their own internal systems for digital delivery. Some of the systems used are commercial software offering with a higher or lesser degree of tailoring to fit individual companies' organizational practices. Others are custom-built for individual companies. The situation is made further complex as the same company may assume different roles across different EPC projects (such as having the role of EPC company in one project, while functioning as vendor of a particular piece of equipment in another EPC project).

How OIP fit into this picture remained challenging for everyone involved. Deciding upon developing a digital resource that the participants could integrate with existing technical and organizational arrangements made it possible to progress without deciding upon the issue. However, as focus for OIP Core shifted towards digital requirements handling, the operators and EPC companies raised questions over the overall architecture OIP was working towards. The underlying concern was about the implications such architectural decisions would have for the (re-)configuration of the digital EPC ecosystem. OIP's participants envisioned two scenarios. One, that OIP would be "an open industry platform that translate different companies' practices into shared technical requirements which helps the industry to improve efficiency and cut cost" (HostCo presentation). Such a digital platform would obviate and replace functionality in the companies' existing systems (such as requirements management), moving it into the platform and the 'common arena'. The other scenario was for a bare minimum but fully standardized system providing a lingua franca for the digital exchange of technical information between companies' existing systems.

HostCo and the software engineers working on OIP Core were the main proponents OIP aiming towards becoming a digital platform. Domain experts on the other hand advocated for the second scenario; to have a shared standardized system that can fit to their existing technical arrangements.

"In our company, we are using a tool for our requirement management in which we can create specification to have the traceability of the requirements. (...) The tool that is developing in OIP project would then communicate with the system we are using now" (Interview excerpt, domain expert)

"The tool we are using is not a competitor to the OIP product, but it is a facilitator providing dynamic information administration. We would use the engine [OIP Core] that comes out of the OIP project to build on our system" (Interview excerpt, domain expert)

Focusing on developing the OIP Core based on the first scenario, failed to encompass the existing systems' functionality. While, domain experts translated HosCo's tendency for development of open platform as their effort for gaining generative potential over OIP's outcome, software engineers referred to their lack of acknowledgment of the existing system' functionality in order to dispense with the overlapping and redundant systems. Indeed, divergent focus on the digital infrastructure innovation and innovation in digital infrastructure lead to the conflicting views over architectural aspects of OIP's outcome.

6 Discussion and conclusion

The above analysis contributes to theory on digital innovation networks in three ways. First, by introducing the temporal dimension in our analysis, we demonstrated digital innovation networks as dynamic and evolving over time. Lyytinen, et al. [3] argue that “the speed and scope of pervasive digitization have created an increasingly dynamic and complex set of social processes in digital product innovation” (p.52), affording new modes of coordination. How and by what mechanisms to coordinate is contingent upon the taxonomy’s two axes of digitizing as operand and operant resource. Including the temporal dimension emphasizes digital innovation networks as ongoing and dynamic, not merely fixed or static entities. As such, not only are the social processes of digital innovation dynamic and complex. They also evolve over time as the configuration of the digital innovation network shifts and evolves. The above analysis traces this as the configuration of companies involved with OIP moved from the pre-project phase of distribution with no centralized control (i.e. anarchic network) towards a more federated innovation network with HostCo as its focal form. Introducing a temporal dimension to digital innovation networks also brings out the tensions that can arise out of such changes. We showed this with regards to modes of coordination. ‘From document-centric to data-centric’ was an effective organizing vision [16] in mobilizing and coordinating companies’ efforts in the loosely coupled, anarchic EPC network. Yet, as the participating companies became more integrated and aligned as a federated network in OIP, this abstract slogan became an ongoing source of confusion as well as contention among project participants seeking to enroll it in favor of their interpretation of project scope and focus.

This argument is similar to Gardet and Mothe [25] observation that different coordination mechanisms are needed as innovation networks evolve. Their observation is grounded in studies of innovation networks in general. Our second contribution is therefore to elaborate upon and substantiate this observation in the context of digital innovation network theory. OIP drew a subset of EPC sector companies closer together in a federated innovation network with HostCo as focal firm. This network came to be coordinated through a centralized project structure with hierarchies and division of labor distributed among sub-projects, along with a work plan with milestones and deliverables. While these mechanisms are well suited to distributing and coordinating more or less clearly defined tasks or activities and for tracking progress through deliverables with deadlines, they do not address what Lyytinen, et al. [3] refers to as knowledge and resource heterogeneity resulting from network participants coming from different organizations as well as professional and disciplinary knowledge domains. As Carlile [26, p.556] notes in the context of new product design “[a]s difference in the amount and/or type of domain-specific knowledge increases between actors, the amount of effort required to adequately share and assess each other’s knowledge also increases.” Framed in the Lyytinen, et al. [3] terminology, with increasing knowledge heterogeneity comes the need for modes of coordinating between professional and knowledge domains.

While HostCo recognized that the organizing vision ‘from document-centric to data-centric’ was inadequate as coordinating mechanism for OIP phase 1, they did not fully acknowledge its function as translator between heterogeneous knowledge domains. Carlile [26, p.556] traces the complexity of collaborating across disciplinary and professional knowledge domains increases with a) knowledge heterogeneity, b) dependence between different knowledge domains, and c) the novelty of the project. While knowledge heterogeneity did not change from pre-project to phase 1, the big difference was that the dependencies across knowledge domains increased, actualizing differences in type and amount of domain knowledge. Drawing upon Carlisle's notion of 'knowledge translation' as a mode of coordinating across heterogeneous knowledge domain, Lyytinen, et al. [3] observe that coordination across knowledge domains requires both cognitive and social translation. The unresolved tension between the divergent views on the nature of digital innovation in OIP (i.e. 'digital infrastructure innovation' vs 'innovation in digital infrastructure') can as such be interpreted as a failure by OIP management to acknowledge the need for coordinating mechanisms in support of cognitive translations across heterogeneous knowledge domains.

OIP management sought to address this issue by giving the workshop on OIP Core. This workshop constituted a form of knowledge transfer from software engineers to domain experts, whereas – thinking in terms of Carlile [26] notion of collaborating across disciplinary knowledge domains – what was needed was a translation between the differing knowledge domains to develop an understanding of OIP goals, processes, and outcome. As such, the workshop solidified the tensions between software engineers and domain experts. Furthermore, digital requirements handling challenges existing industry and professional structures. Such questions are resolved through social translations, that "involve constant interaction and political positioning among innovation network participants [whose] perspective are often in conflict, but they still need to find a way to modify and align their interests into temporary dialectic synthesis" [3, p.56]. Therefore, the ending of OIP phase one can be understood as a failure to negotiate the open-ended and generative potential of OIP Core as envisioned by HostCo's software engineers, against the installed base of previous investments among the EPC sector companies' knowledge base, technical know-how, standards, and existing tools. This leads us to the third and final theoretical contribution, the embeddedness of digital innovation networks.

OIP shares a similar structure to Boland , et al. [27] digital innovation network centered on a key firm. Boland et al.'s study shows that the focal firm enforces a transformation throughout the network of subcontractors and vendors delivering goods and services. While HostCo assumed a similar position in the innovation network, its ability to enforce an agenda did not match that of Boland et al.'s focal firm. A key difference between the two cases is the broader network of companies the two digital innovation networks are embedded in. While Boland et al. offers a case study of designing and constructing a novel building, the 3D construction drawing tools enabling such novel design are in more or less widespread use throughout the construction industry. As such, the installed base of technological know-how, disciplinary knowledge was to a large degree already oriented around 3D drawings. In the case of OIP, however, there was no such alignment of the installed base. Rather, OIP's outcome needed to fit with the participating companies previous technological and organizational investments in different approaches to digital delivery. While it is not correct to say that OIP management did not acknowledge this, our analysis illustrates how digital innovation coordination needs to encompass the tension between generativity and open-ended potential of digital innovation [2] with the digital infrastructure's installed base.

The practical implication of our study relates to networks of projects' participants. Due to the fact that digitalization changes the way innovation unfolds, from a single firm to the networks of actors, considering the heterogeneity and distributed features of innovation networks are at the core. Based on the networks' configuration (whether it is heterogenous or homogenous, centralized or decentralized), coordination needs to be considered as an evolving and achieved accomplishment. Respectively, the first feature characterizes that although networks of actors may not be changed through the project, new modes of coordination are required as projects progress to the next stage. In our case, the reason why challenges arise was lack of proper coordination and ability to align the coordination mechanisms to the changes when projects progress to the next phase (i.e. from preparatory phase to the project proper).

More importantly, the embeddedness of innovation networks may exist in large-scale projects. For instance, as we showed in our case, the project network was embedded in an industry network which made some challenges in coordination mechanisms. Therefore, differentiating the industry level and organizational level strategies is vital in coordinating such complex and large-scale projects.

In concluding, by focusing on the innovation networks we have provided insights about how and why challenges arise during large-scale and complex projects, yet future researches are needed to discuss the possible solutions in coping with such challenges. For instance, future studies can investigate different coordination mechanisms (especially the ones used in more heterogeneous and distributed networks of actors) and how they affect the project progress.

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