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Integrating knowledge in infrastructure projects: the interplay between formal and informal knowledge governance mechanisms

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ABSTRACT

This study focuses upon knowledge governance mechanisms of integrating specialised knowledge on underground utilities in large infrastructure projects. The integration of knowledge is essential for the realisation of such projects. The study explores the formal and informal knowledge governance mechanisms in three large infrastructure projects and compares these mechanisms to reveal their effects on knowledge integration. The findings show that combining reward systems, project culture and trust are targeting the motivation of underground experts to share their knowledge and allocation of authority and project network are mechanisms aimed at the coordination between managers and underground experts to integrate knowledge. We contribute to studies on knowledge governance by enabling further empirical insight in the relationships between formal and informal mechanisms.

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Knowledge governance; governance mechanism; knowledge integration; underground utilities; infrastructure projects

Introduction

In recent decades there is a growing interest in the debate on knowledge governance in projects (Grabher 2004, Pemsel and Müller 2012, Pemsel *et al.* 2016). Knowledge governance is about “choosing organisational structures and mechanisms that can influence the process of using, sharing, integrating, and creating knowledge in preferred directions and toward preferred levels” (Foss *et al.* 2010, p. 456). Knowledge governance is a relevant topic for projects as knowledgeable actors work in fragmented fields of various functionalities (Harper 2014). These actors have acquired specialised knowledge over many years of experience. This knowledge needs to be governed, shared and integrated in order to fulfil the project’s goals (Fellows and Liu 2012).

The governing, sharing and integrating of knowledge in large infrastructure projects is a real challenge. Large infrastructure projects are characterised as uncertain, complex, politically-sensitive, usually commissioned by governments and with multiple public and private actors (Brunet 2019). These characteristics especially hamper knowledge integration (Von der Tann *et al.* 2020). Knowledge integration is here

defined as “the process during which individuals, who derived different solutions and experiences in specialised fields, contribute their expertise with the purpose of meeting a shared aim” (Ruan *et al.* 2012, p. 8). To integrate knowledge in large infrastructure projects specific attention for knowledge governance is thus required.

Knowledge governance mechanisms are means that projects deploy to influence the behaviour of actors and stakeholders to integrate knowledge (Sitkin *et al.* 2010, Foss and Klein 2013). Scholars distinguishes formal and informal knowledge governance mechanisms, which are respectively direct and indirect ways to influence knowledge integration (Grandori 2001, Wiewiora *et al.* 2014). Earlier project studies on knowledge governance have predominantly theorized on the mechanisms that influence project actors to align projects and teams in permanent organizations (see Foss *et al.* 2010, Pemsel and Wiewiora 2013). For example, Pemsel *et al.* (2014) developed a conceptual framework addressing the micro- and macro-level elements of knowledge governance and their mutual interactions. Knowledge governance is strong in “accounting for the microlevel mechanisms that link governance mechanisms and knowledge processes”

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(Foss 2007, p. 47). To further our understanding of knowledge governance in large infrastructure projects, it is crucial to examine how the various governance mechanisms relate to each other when contributing to the integration of specialised knowledge (Demirkesen and Ozorhon 2017). In line with this scholars (i.e. Zahra *et al.* 2020, Song *et al.* 2022) ask for more studies to provide empirical groundwork that further showcases the dynamics of real-life knowledge governance mechanisms.

Therefore, the aim of this paper is to explore the formal and informal knowledge governance mechanism for the integration of specialised knowledge in infrastructure projects. We transform this aim into the central research question *how do specific combinations of formal and informal knowledge governance mechanisms affect knowledge integration?* To answer this research question, we conducted qualitative research on knowledge governance mechanisms to integrated knowledge concerning underground utilities in three large infrastructure projects. Inadequate integration of knowledge concerning underground utilities, such as electrical power, sewer, water and telecommunication networks, causes risks for infrastructure projects. These risks cannot be completely predicted and known at forehand and thus can lead to time delays and cost overruns (Vilventhan and Kalidindi 2016, Biersteker *et al.* 2021). Knowledge integration on underground utilities is particularly paramount during the design phase (Chen and Xie 2017). The study has been executed between 2019 and 2020, in which over 70 semi-structured interviews were conducted. This type of interviewing allows for freedom to explore project participants' opinions in a conversational tone, but also allows for standardization (O'Reilly 2005).

The findings of our study reveal the relationship between the different knowledge governance mechanisms and the differences in the way mechanisms affect knowledge integration within projects. This study contributes to the knowledge governance debate (Grabher 2004, Pemsel *et al.* 2014, Ali *et al.* 2018) by showing the interplay between formal and informal knowledge governance mechanisms, which was asked for by other scholars (Zahra *et al.* 2020).

The structure of the article is as follows. First, the theoretical outline works through literature on knowledge governance in projects, knowledge governance mechanism and knowledge integration. In the methodology, the three cases, the qualitative research methods and the process of analysis of data are described. In the findings section, the study describes the formal and informal knowledge governance

mechanism and explains the extent to which integration took place within the three projects. The discussion outlines the value of the findings for knowledge integration and knowledge governance. Finally, conclusions are drawn, and contributions to the knowledge governance literature are reflected upon.

Theoretical framework

Knowledge governance and projects: motivation and coordination

The debate on knowledge governance in management and organization studies is ongoing for two decades (Grabher 2004, Foss 2007, Phelps *et al.* 2012, Zahra *et al.* 2020). This debate distinguishes diverse dimensions influencing the effective integration of knowledge in organisations (Grandori 2001), but the motivation to share knowledge (Huang *et al.* 2013) and the coordination to create opportunities for sharing knowledge (Asrar-ul-Haq and Anwar 2016) are the most frequently mentioned. For example, a conflict of interest between actors in an organization abates motivations to share knowledge. These insights from management and organization studies can be helpful for understanding knowledge integration in projects (e.g. Foss 2007).

Some scholars point to the specific characteristics of large infrastructure projects which might hinder the applying of these insights (Grabher 2004). Such projects can be characterized as temporary inter-organizational endeavours, with clear goals and a clear ending (Sydow *et al.* 2004). Large infrastructure projects are composed of a large number of actors from multiple organizations or organizational units with specialised knowledge and skills trying to achieve the project's objectives (Lech 2014). These projects face challenges to effectively align the various specialised project activities due to difficulties to understand each other's work (Demirkesen and Ozorhon 2017). Large infrastructure projects also operate under conditions of ambiguity and uncertainty, which generally requires project management to govern the problem-solving mechanisms that are related to these uncertainties (Ahern *et al.* 2014). Finally, after the termination of a project actors return to their "eco-systems" (Grabher 2004).

These characteristics challenges the integration of knowledge within large infrastructure projects (Grabher 2004, Pemsel *et al.* 2014, Ali *et al.* 2018). A first challenge is the enormous task differentiation which hinders the exchange and integration of knowledge (Demirkesen and Ozorhon 2017). Secondly, El-Gohary

and El-Diraby (2010) and Nicolini *et al.* (2001) observed a tension between the integration of knowledge and the integration of other project resources, such as information and materials. A third and final challenge is the cultural diversity of the companies that participate in knowledge-sharing activities (Celadon and Sbragia 2020). Fellows and Liu (2012) see these challenge as a culprit for project failures. Therefore, the retention of valuable project knowledge and the prevention of post-project “amnesia” is a central concern for projects (Tshuma *et al.* 2018).

Notwithstanding these challenges, research on knowledge integration in projects have shown that the dimensions of motivation and coordination to integrate knowledge seems also pervasive (Koppenjan *et al.* 2008, Pemsel *et al.* 2016). For example, motivation is reflected in the project actors’ preference towards a specific way of interacting with other project actors (Pemsel *et al.* 2016) and in the executive’s competences to convince his employees to share knowledge (Pemsel and Müller 2012). The coordination to integrate knowledge is shown in the effectiveness of the coordination of specialised units within a project (Koppenjan *et al.* 2008, Javernick-Will and Scott 2010) and in the synchronizing of different time orientations of teams in a large project (Söderlund 2010).

Formal and informal knowledge governance mechanisms

In the literature on knowledge governance a distinction is made between formal and informal governance mechanisms influencing the behaviour of project actors and stakeholders to integrate knowledge (Foss 2007, Michailova and Foss 2009). Grandori (2001) used formal and informal mechanisms to describe knowledge sharing processes within and between firms. Other scholars examined the interplay between knowledge governance mechanisms, the motivation to share knowledge and knowledge sharing behaviour (Huang *et al.* 2013), or studied the mechanisms that coordinate knowledge sharing (Husted *et al.* 2012).

Scholars of knowledge governance studying informal knowledge governance mechanisms most frequently mentioned project structure, allocation of authority, reward system and steering as mechanism (Grandori 2001, Foss *et al.* 2010, Müller *et al.* 2016b). Project structure determines the formal relations between the various tasks and roles in a project, but also the formal communication patterns between the project actors (Foss *et al.* 2010). In general, projects

have a strongly decentralised structure (Dubois and Gadde 2002). Communications between the different fragments of the project need to be clearly organized to enhance integration (Grant 1996). The allocation of authority to project actors (Müller *et al.* 2016a, 2016b) is another formal mechanism. Authority is concerned with the power of actors to make decisions with appropriate information (Foss 2007) as it is beneficial to have clarity on who has authority in the integration of knowledge. The relationships between the various allocations of authority resembles the project structure (Foss *et al.* 2010). Additionally, the third formal mechanism is the reward system (Grandori 2001), which aims to facilitate actors to share knowledge. It is the formalised way by which projects reward knowledgeable actors so they repeatedly share their knowledge (Söderlund 2008). Reward systems range from monetary rewards, for example a bonus, to non-monetary rewards, for example a formal praise and public recognition but can also be an intrinsic reward, such as pleasure that is derived from the performance itself (Bartol and Srivastava 2002). The fourth and final formal mechanism is the steering by managers on the interaction between different actors in a project. Managers deploy various strategies to steer the process towards the realisation of useful knowledge between actors (Pemsel *et al.* 2016). Essential for knowledge integration is the development of good relations between actors (Söderlund 2010, Tortoriello *et al.* 2012).

In addition to these formal mechanisms, scholars of knowledge governance mentioned the informal knowledge governance mechanisms of project network, project culture, trust and steering. The first mechanism is project network, which structures project actors and the flow of knowledge between them (Dyer and Nobeoka 2000). Tsai (2002) argues that these networks show the actual integration of knowledge in daily life. These networks are generally construed based on friendship networks, trust networks, advice networks, etc. The second informal mechanism is the creation of a project culture which is open to reflection and discussion (Wiewiora *et al.* 2014, Mueller 2015). This refers to the project’s implicit and explicit shared norms and values, assumptions and expectations in sharing knowledge (Ruijter *et al.* 2020). Pemsel *et al.* (2016) note that a project culture relates to the collective values that actors have on knowledge integration. Projects should aim to create a culture in which actors perceive a greater accessibility to tacit and codified knowledge (Poleacovschi *et al.* 2019).

The third most frequent mentioned informal mechanism is the concept of trust, which enables stronger relationships between actors, yielding useful knowledge (Uzzi 2018, Cerić *et al.* 2021). Trust between actors makes it more likely that the expertise will also be utilised (Levin and Cross 2004, Ruijter *et al.* 2020). The fostering of trust increases the quantity and quality of knowledge sharing, but also increases the chances of the knowledge being utilised within the project (Ruijter *et al.* 2020).

Based upon the theoretical discussion above, the relationship between the dimensions motivation and coordination and knowledge governance mechanisms under examination (see Figure 1).

Methodology

To answer the central research question, we adopted a qualitative research approach. A qualitative approach is focussed upon project actors' interpretation of and experiences with formal and informal governance mechanisms contributing to the integration of knowledge (Yanow and Schwartz-Shea 2015). The researchers

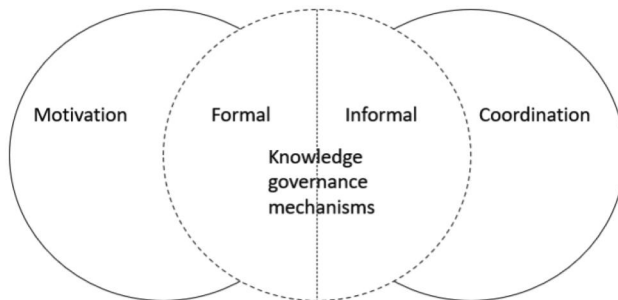


Figure 1. Theoretical framework. The two knowledge governance dimensions with a partially unknown overlapping knowledge governance mechanism. The framework shows the uncertainty on what type of formal and informal knowledge governance mechanisms falls into which dimension.

use the distinction of Legewie (2013) to identify which governance mechanisms have produced knowledge integration. Legewie (2013) asks questions such as; “is a condition X necessary or sufficient for outcome Y?” and “which configurations produce outcome Y?.” In our study, we suggest that (a combination of) mechanisms could be hierarchically positioned to one another.

We chose a multiple case study (Yin 2017) to compare three cases of large infrastructure projects that have a significant impact on the underground. To distinguish relevant from less relevant mechanisms, it is important to carefully select the cases (Yin 2017). George and Bennett (2005) give three criteria for case selection: (1) the available data must provide an opportunity to study the complexity of the contexts; (2) the cases need to be relevant for the research objective and (3) cases must provide diversity across contexts. In line with these criteria, all our cases needed to integrate knowledge on underground utilities in the project design teams. The three cases are adjustments of railway, airport and highway infrastructure networks (see Table 1). Taken together, the selected cases are relevant and relatively similar enough for comparison.

Data collection

The strategy for data collection followed different steps. The main source of data collection was through semi-structured interviews, non-participant observations and document analysis. To promote the credibility of the data, the researchers used a triangulation of data sources. The details of the data collection methods are shown in Table 2. Observations were made by the first author in the role of “participant-as-observer,” which means that the identity of the researcher is known to those being studied, but the researcher holds a neutral position when observing (Worline

Table 1. Case study selection (according to criteria of George and Bennett 2005).

Case study	Criteria 1: data accessibility	Criteria 2: research objective relevance	Criteria 3: case diversity across context
Airport project	Researcher receives internship card; researcher is involved in meetings; researcher receives sensitive documents such as contract and tender documents	Underground utilities need to be relocated as part of an overall project goal	The overall project is conducting a terminal construction; utility owners are the asset managers of the airport; context is considered complex
Railway project	Researcher has access to important project actors and project stakeholders; researcher has gained access to drawings; researcher accessed development plans	Underground utilities need to be relocated as part of an overall project goal	The utilities are part of a project that constructs an elevated railway; utility owners are private companies; context is considered complex
Highway project	Researcher has access to important project actors and project stakeholders; researcher accessed development plans	Underground utilities need to be relocated as part of an overall project goal	The utilities are relocated as part of the construction of a new highway which includes a tunnel; some parts of the project are considered complex; utilities are owned by private companies.

Table 2. Methods of data collection in case studies.

Case	Period	Data collection methods
Airport project	January–December 2019	44 semi-structured interviews with project actors and project stakeholders; observations in 10 meetings; reviewing dozens of documents related to the tender
Railway project	February–September 2020	17 semi-structured interviews with project actors and project stakeholders; discussed drawings of underground utilities; reviewed publicly available documents related to the project
Highway project	March–October 2020	12 semi-structured interviews project actors and project stakeholders; reviewed publicly available documents related to the project

2012). Observational data and documents were predominantly used to add context and triangulate the interview data which would promote the credibility of the sources.

The interviews formed the basis for the empirical description and started with project managers. Through a snowball effect, we were redirected to other project actors such as project directors, utility experts, designers and public supervisory authorities, until saturation was reached (Patton 2014, Yin 2017) (see Appendix A for overview interviewees). A total of 73 interviews were conducted with 68 respondents as some respondents have been interviewed for both the railway and road projects. In the findings section respondents are referred to by their category and project, for example as Respondent 1.2b, which refers to a project manager of the railway project. By using semi-structured interviews, the researcher was able to stay close to the relevant concepts and relationships within the project but also allowed to probe into asking for detailed examples of the project (O'Reilly 2005). The interview topics were derived from the theoretical discussion; formal project structure, allocation of authority, reward system, project network, project culture, trust and steering. The operationalization of the concepts is described in Table 3. The main purpose of the interviews was to gather detailed information on the indicators that are derived from the theoretical concepts that the researchers have deployed. All the interviews were transcribed. Throughout the end of the data collection period, the researcher focussed more on corroborating data or filling in missing links in the process description (Hermanowicz 2002). All interviews have been transcribed and observation and document data have been documented.

Data analysis

The data was analysed based on a co-variational approach which assumes that the causal relationship between the independent and dependent variable is deterministic and invariable (Blatter and Haverland

2012). A co-variational approach is about determining whether a certain factor has an effect. Adopting a co-variational approach in comparatively analysing different cases is well established within social and project studies (Jordan *et al.* 2011). Four steps were taken to analyse the raw data from the interviews, observations and documents. In the first step, we went through all of the data and coded the sections that were related to one of the knowledge governance mechanisms. This way we laid out an in-depth analysis of each project separately by examining the presence of each knowledge governance mechanisms. This way, it was possible to understand how within each project the specific knowledge governance mechanisms were shaped.

The second step consisted of determining which project integrated their knowledge best. This was done by coding the data that was related to knowledge integration and subsequently determine which case integrated the knowledge best. This determination was based on the project actors' assessment in evaluating the formal design product. By establishing which project was able to integrate their knowledge best, it became clear which projects should be compared to explain the difference of knowledge integration between the three projects.

In the third step, the researchers value the contribution of individual knowledge governance mechanisms to the knowledge integration. The valuation of each specific knowledge governance mechanism is judged per case. The researchers judged the governance mechanisms by using a classification rubric of low (L), medium (M) and high (H) to describe the extent to which each governance mechanism per case contributes to knowledge integration in that particular case. L within the rubric means that no effect was determined, M means that an effect seems to be there but it was not clearly described by respondents, and H means that an effect was clearly present. The valuation of each mechanism is predominantly based on the ways in which respondents describe the connection between the mechanism and the knowledge integration in their project. In Table 4, we provide an

Table 3. Operationalization of the concepts.

Concept	Definition	Indicator	Data gathering
Project structure	The structure within the project through which project actors formally relate to each other	Organizational structure of the project	What are the formal positions/roles within the project? How do these positions/roles relate to each other? How is the project structured?
Allocation of authority	The power of actors to make demarcated decisions with appropriate information	The formal job description of the project actors	What do the different positions/roles do? What is considered the sphere of influence related to the positions?
Reward system	It is the standardized process through which projects reward knowledgeable actors for sharing knowledge	The way project actors are requested to report about their tasks	What are the means/procedures by which knowledge get integrated? What was the formal response to the integration of specific knowledge?
Steering	The manager's steering on the knowledge process based on the perceived misdirection of the project	The decisions that key project actors make to align project actors	What are the decisions key project actors have taken while the design phase was already underway? What are the motives for intervening in the process?
Project network	The informal process that emerges from interactions between heterogeneous actors	The interactions that emerge to develop the design	Who's involved in the integration of underground utility knowledge in the design? What transpired throughout the process?
Project culture	Culture is the project's shared values, assumptions and expectations on a specific topic	The collective conception of underground utility knowledge	What are the ideas about underground utility knowledge? How do project actors perceive the role of the underground within the design?
Trust	The psychological state comprising the intention to accept vulnerability based on positive expectations	The perceived trust between project actors and project stakeholders	Who trusts each other in sharing knowledge inside and outside the project?
Design	The outcome of the design phase	The individual assessment of the formal product at the end of the design phase	What did key project actors think about the final result of the design?

example of a valuation of through the knowledge governance mechanism of allocation of authority.

In the fourth and final step, a cross-case analysis was executed to validate the differences between the mechanisms, which could explain the differences in knowledge integration between the projects (Eisenhardt 1989). With this analysis, researchers were able to ensure the robustness of the data and provide detailed differences between the cases. This step consisted of grouping mechanisms, which were equally standing out compared to others. In line with Legewie (2013), we decided that most contrasting mechanisms are considered more important mechanisms than lesser contrasting mechanisms to integrate knowledge. When we have established which project integrated their knowledge best, we can distil which mechanisms best explain the variation between knowledge integration across the different projects. For example, if we establish that project A is best in integrating knowledge, and trust is valued as H, in contrast to L for both the other projects, than we infer that trust has a relatively strong influence in knowledge integration.

Table 4. A valuation example of allocation of authority.

Project	Indicator	Value
Airport project	L was given to the case in which multiple managers were responsible for the underground and it was unclear if how integration took place at all across the different managers.	L
Railway project	M to the case that had a manager who was responsible for underground utilities, but he did not have much "influence in decision-making, he just needed to report back to the project director" according to the manager utilities.	M
Highway project	H is given to the case with the actor who showcased the clearest authority over the underground. The manager conditioning got a stronger "mandate to decide on issues," according to the project manager.	H

Findings

In this section, the findings are presented by first describing the formal and informal knowledge governance mechanisms in the three studied projects. We then discuss the extent to which knowledge integration has occurred in the design phase of each project.

Finally, the comparative analysis shows which knowledge governance mechanism dominate knowledge integration.

Formal knowledge governance mechanisms

Project structure

The three studied projects had a similar organizational structure of the project to govern knowledge on the underground utilities. In each project a knowledgeable actor on underground utilities was supervised and represented in the management team by a manager. Consequently, in the management teams' discussions knowledge on the underground utilities was never directly at table, but always represented through a manager (Observation, 13 March 2019). The airport project had a management team consisting of a project director landside, a commercial lead and a design lead. The utilities project manager reports directly to the project director landside. In meetings regarding progression of utility relocation, the utilities manager provides insights towards the project director landside together with the representatives of the underground (Observation, 6 March 2019).

Both railway and highway projects, are structured according the so-called Integrated Project Management model, which is the integration of diverse roles in one team, such as contract manager, stakeholder manager, technical manager, project manager and manager risk control. "Together we are conducting the project" (Respondent 1.3c). In the IPM model, the technical or stakeholder manager supervises the utilities. In the railway project it is both the stakeholder and technical manager who supervise utilities. The project manager argues; "if we talk about design and relocate utilities, it is the responsibility of the technical manager. But during the execution it is more often the case that stakeholder management become responsible" (Respondent 1.2b). In the highway project the manager underground conditioning is "basically is a stakeholder manager for the underground, and not necessarily a technical manager" (Respondent 1.3c).

Allocation of authority

The power of project actors to make decisions with appropriate information on underground utilities was strongly related to the tasks and responsibilities of manager who is acting as the delegated principal authority towards the agent, in casu an engineering firm. Both airport and highway projects, outsourced

the design task to an external engineering firm. When an engineering firm is contracted, both projects appointed a manager who specifically focussed on managing underground utilities in the design. The role of the utilities project manager in the airport project was designed to "take responsibility of the utility dossier" and to "coordinate" the engineering firm to get the knowledge they needed to make the design (Respondent 1.3a). This project manager utilities argued, however, that he did not have much "influence in decision-making, he just needed to report back to the project director." The manager conditioning in the highway project was responsible for "the stakeholder management which relates to all aspects of the underground" (Respondent 1.3c), which allowed him to "partake in different meetings with different representatives of the underground." He also got a stronger "mandate to decide on issues," according to the project manager. The designers from the municipality in the highway project describe the conditioning manager as "the man of the underground is someone you can built on" (Respondent 2.2b), and the utility owners of the airport project argue on working with the utility manager "it is nice to start the project with [him]" (Respondent, 2.2c).

The railway project didn't outsource the design, but hired specific project actors to their project organisation. The technical manager argues "with these types of projects I am a strong supporter of reeling in people instead of firms" (Respondent 1.4b). While the railway project did not hire an engineering firm, they also did not have an underground utilities manager but one utility expert, who did the technical analysis of the underground design. Consequently, "there are multiple managers deciding on the underground utilities, and allocation of responsibilities is managed during meetings" (Respondent 1.2b). The project manager argued "it depends on the situation, if the underground falls under technical or stakeholder manager" (Respondent 1.1b).

Reward system

The standardized process through which the designers receive knowledge of underground utilities in the projects varies greatly. The airport project standardized knowledge sharing through "the system engineering approach [which means that] the engineering firm's design is based on a list of requirements" (Respondent 1.3a). The designer of the engineering firm therefore needed to obtain requirements from utility owners and utility experts of the airport to draw their design. A designer argues "it is an easy division of labor, there

is back-and-forth between the principal and client to share knowledge that needs to result in a draft design in which everyone has their input" (Respondent 1.7). However, the designers of the client were critical in their way that the principle tried to share their knowledge: they "wanted to think in terms of solutions and not in terms of requirements" (Respondent 1.7a). The utility experts of the principal felt "excluded" in drafting a design.

In the railway project, the standardized process was to request knowledge from utility experts in response to design decisions about the surface edifice. For example, when the surface design was ready, the technical project manager requested such as the development of an inventory of what was in the underground. With the delivery of an inventory of the existing utilities, "it would be easier to see the consequences of design decisions for utilities" (Respondent 1.5b). Also, first a proposed surface design was made and then the technical manager asked a response from the utility experts. A utility expert argues "if the project team made a draft or changes to a draft, they then asked if we could live with these changes" (Respondent 1.5b). Because the utility experts were the last in the chain of the design process, they felt "lost and isolated" at times. A utility expert argued "first you say that there is no relocation needed [based on the inventory] and then suddenly 18 to 40 relocations are necessary" and "we can only react on what is coming and can barely anticipate" (Respondent 1.5b).

The highway project specifically did not want a system engineering approach as installed by the airport project, but standardized the reception of knowledge by clearly describing, a priori any design decision was made, what the utility experts could contribute in relation to what the project wanted to accomplish. The manager conditioning argued that "I just need to be able to say what I want to the people that can help me best" (Respondent 1.3c). Consequently, the conditioning manager talked with the utility experts of the municipality and the engineering firm about what "he wanted" and provide "freedom" to the utility experts to develop a design that fits the needs. Therefore, utility experts were able to translate their knowledge through a clear idea of what the recipient wanted to have. A utility expert of the municipality says about this alignment; "there was a blueprint about what they wanted to have, and this was a guideline in preparing for the design to see where there are opportunities for us" (Respondent 3.5).

Steering

The project manager utilities of the airport project mostly steered on the process by doubling down on the initial set of rules on which the cooperation was predicated. He had to steer on the process because as he argues the "confusing and contradictory demands" needed to be addressed (Respondent 1.2a). Also certain designers were not able to conform to their initial approach and therefore the project manager utilities "needed to send people out" (Respondent 1.3a). The project manager utilities had to stop utility experts from "continuously giving solutions instead of requirements" (Respondent 1.2a). The lack of clear requirements made it difficult for the designers to work. A designer states that "I was frustrated with the way of working at the project" (Respondent 1.7a). In agreement with the project manager utilities, a process manager of the engineering firm "had to write down the requirements that were given and the agreements that have been made" to push the design forward (Respondent 1.7a).

The interactions in the railway project needed steering. The steering of the project manager in the railway was aimed at attracting "heavyweight specialists" to tackle the piling challenges. The project manager remembers "we needed to intervene, because problems started to pile up" (Respondent 1.2b). To steer the interaction, the project manager hired an experienced utility expert that got the task to "align and clarify the interests of the underground within the project" (Respondent 1.2b). Also, the technical manager admitted that the technical team was "unbalanced" (Respondent 1.4b), and he steered by adding utility experts to the design team so that they could help to "get a better picture of the underground risks" (Respondent 1.2b). The steering of the managers was not without challenges because the utility expert needed to "fight himself into the team" to make significant changes to the design (Respondent 1.5b). Unfortunately, the changes were made "relatively late," because important deadlines could not be met anymore (Respondent 1.5b).

The highway project's conditioning manager did not steer the process extensively, but tried to maintain his vision. He remarked that he kept on with his plan to keep steering on clarity of the goal of the project. He organizes meetings frequently at the beginning of the trajectory to clarify the goals and "made sure that they [project participants] were felt important." He argues "I steer on the 'what' that we want, instead of what the requirements are for what we want" (Respondent 1.3c). To assure that the interpretation

was shared by others, he “monitored the situation closely at first, and when everything is clear, we meet less frequently but I keep a finger on the pulse” (Respondent 1.3c).

Informal knowledge governance mechanisms

Project network

In the airport project, the informal interactions between the various project actors on the underground are shaped by two groups who lack past working experiences. On the one side, there are the utility owners and experts of the airport and the utilities PM, which characterizes their relationship as; “we can read and write together” (Respondent 1.3a). On the other hand, there is the designers of the engineering firm who according to the utility owners of the airport “have no knowledge of how it works at their airport.” The designers of the engineering firm agreed that “process of cooperation are working differently at the airport than in the rest of the Netherlands.” For example, the many meetings were influencing how project actors interacted, there was a so-called “meeting culture” (Respondent 1.3a). The designers of the engineering firm described this practice as an overload “we are not used to so many meetings” (Respondent 1.7a). The many meetings with different participants also left designers with conflicting requirements. The designers denote “at all meetings new and conflicting requirements were presented” (Respondent 1.2a).

From the interactions in the railway project a network emerged in which utility experts from the project and municipality were loosely connected with the project and stakeholder managers. The utility owners, for example, thought that “they were involved too little in the specifics and decision-making of the project” (Respondent 1.5b). A permit provider of the municipality describes “in cooperation with [a utility expert of the project], we frequently come together to look where we could relocate utilities to for specific projects but there was no overall vision” (Respondent 3.3b). This is because the utility expert of the project had no previous working experience with members of the technical team and mostly worked in isolation from this team. A utility expert argues that “I need to put the foot down to get attention, otherwise people are not giving it to you” (Respondent 1.5b).

The highway project’s network was shaped by the interactions between the conditioning manager, utility experts, permit providers from the municipality and designers from the engineering firm. The ties between

the actors were considered strong because of past working experiences. The designer of the municipality said “most of us already have known each other from previous projects” (Respondent 3.2b,c). The project manager of the engineering firm wanted to include utility knowledge and therefore hired a utility expert who was involved in the project from the beginning. He elaborated by saying; “this allows for continuity in the project and decreases engineering time” (Respondent 1.2c). The conditioning manager met “regularly” with the engineering firm to discuss the goals of the project. The permit providers of the municipality were closely involved because of the relocation of utility roots, just like they were in the railway project (Respondent 3.3b).

Project culture

The shared values, assumptions and expectations on underground utilities in the airport project is largely revolving around the idea that the underground is supportive to the overall project’s goal. The utility experts argue that “we are supportive of the project” (Respondent 1.5a), and the project should not be “troubled” by underground utilities. Although the project director argued “the underground is critical in constructing the project” (Respondent 1.1a), the underground utilities “ha[d] been forgotten” in the early stages of the development of the project (Respondent 1.3a). This has “set the tone for the rest of the project” according to a utility expert (Respondent 1.5a). The underground should be flexible in the development of the design, which means that project managers need to rely on utility experts to find technical solutions if needed. Also, utility experts feel this way, this is reflected by a utility expert asserting “until now there is always a technical solution to be found” (Respondent 1.5a), meaning that underground utilities should be.

Also in the railway project, it was generally perceived that the underground was merely supportive and undervalued within the project. A project director argues “it could be that we underestimated the complexity [of the underground] in the area” (Respondent 1.1b). It was argued that the “focus is mostly on the surface” (Respondent 1.5b), and utilities were considered “difficult” (Respondent 1.2b). A project manager recalled “this is a problem not just for this project, but all around in this organization, I do not know why. Everybody knows the underground can be a game stopper” (Respondent 1.3b).

The conditioning manager and the project manager from the engineering firm in the highway project,

however, describes the underground as “an integral part of the project”. He doubles down by stating that “the underground is considered one of the top priorities in the project” (Respondent 1.3c). This generated an atmosphere where utility experts “knew that the project is counting on them” (Respondent 1.3). Utility experts argue that “in an early stage initiative was taken to assemble the different [utility disciplines and designers]. Eventually this cooperation was a nice supportive committee for issues that emerged later on” (Respondent 3.5b,c). This cooperation helped the utility owners and utility experts from the municipality to be “taken seriously” in considering technical aspects of the design (Respondent 2.2b,c).

Trust

Trust as a positive expectation towards others in the projects was predominantly determined by past working experiences. In the airport project, the project manager utilities trusted the group of utility experts and owners, because “they have known each other for a long time” (Respondent 1.3a). There was, however, a lack of trust with other members outside the group of these knowledgeable actors. There was, for instance, less trust between the project director and the utility experts, which became apparent when the project director said “why would I follow their advice, if they got it also wrong so many times” (Respondent 1.1a). There was also not much trust between the utility experts and the designers from the engineering firm. The utility experts argued that “[the engineering firm] do not know the area here, we expect them to listen to what we have to tell, but they do not” (Respondent 1.5a).

In the railway project, the utility experts and owners did generally trust each other. There was trust, for example, between the utility expert of the design team and the municipality. This was reflected a utility expert who said “the utility world in this area is a small world, you know each other, you can rely on each other because they know how things are organized” (Respondent 1.5b). However, there was a lack of trust between utility experts and owners and other project actors. The project manager characterised the behaviour of utility owners as “occasionally bordering on blackmail” and “opportunistic” (Respondent 1.2b). At the same time, the representative of the utility owners said about the cooperation with the project, “it is just related to people, and with other projects, yeah, we experience better connection with other projects” (Respondent 2.2b,c). Furthermore, the utility expert in the design team did not feel that he was trusted by other actors of the design team. A utility

expert denotes that people changed design documents. Although you want to do it together, but yeah, when they are changing behind your back, you cannot rely on them (Respondent 1.5b).

Also, past experiences made actors trust each other in the highway project. The representative of the utility owners said “we [utility owners] can rely on him. [The conditioning manager] is an amiable man. I have worked for many years with him” (Respondent 2.2b,c), while the project manager from the engineering firm conveyed his trust by saying “he is a man of his word” (Respondent 1.2c). Also, an underground designer argued “I was hired to help the design team, and everybody helped me settle really fast. because I worked on the project for a long time they accepted my expertise” (Respondent 1.7c), which shows the level of accommodation that the design team showed in integrating the expert of the underground.

Knowledge governance mechanisms contributing to knowledge integration

In this paragraph, we first indicate which project integrated their underground utility knowledge best in the design, before we turn to a comparison between the knowledge governance mechanisms that could explain the difference in knowledge integration between the three projects.

We infer that the highway project was best able to integrate underground utility knowledge in the project design. This conclusion is predicated on the statements made by project managers, utility experts and utility owners. For example, the representative of the utility owners argued that this project was able to “clearly described [the utility owners’ interest] in the tender” (Respondent 2.2b,c). Furthermore, it was argued that “the delivery of the design was completed within schedule,” as argued by the project manager (Respondent 1.1c). And finally, most of the interfaces with the surface were covered, although, according to a designer, “there were some last-minute adjustments to tackle small details” (Respondent 1.7c).

The airport and railway projects were both considered “flawed” by their own standards (Respondent 1.7a). Concerning the airport project, a utility expert of the contractor who won the tender recalled that “there were street lights coupled with water pipelines” (Respondent 1.7a). In this project, the requirements of the utility owners were also “easily overlooked” (Respondent 1.5a). The railway project also had an inadequate knowledge governance. The reference design was “problematic” because its delivery was

delayed, which could have potentially resulted in the loss of “millions of euros of European subsidies” (Respondent 1.1b). Additionally, due to time constraints, the legal department had misinterpreted the “constructions to protect utilities, which was obvious for people with knowledge on utilities, but these people misunderstood the obvious” (Respondent 1.5b). Because of this “misinterpretation,” the requirements as set by the utility owners were not well translated into the tender documents (Respondent 2.2b,c).

Knowledge governance mechanisms

Because the highway project was considered best able to integrate underground knowledge within the design, the study juxtaposed this project with the other projects to determine the knowledge governance mechanisms that account for the differences between the projects. When comparing the knowledge governance mechanisms of the three projects, it becomes apparent that three governance mechanisms are considered the most crucial on knowledge integration; reward system, culture and trust (see the bold rows in Table 5). This can be seen at the relatively high scores of the governance mechanisms of the highway project in relation to the lowest possible scores of the other projects. Additionally, less influential governance mechanisms are authority and network structure, which seem to influence knowledge integration but might be prerequisite for knowledge integration.

The *reward system* in the highway project motivated knowledgeable actors to participate in finding inventive design solutions within a clear scope of the project’s goal. In contrast, the reward system in the airport project discouraged underground experts to provide knowledge because only within the list of demands experts could add their knowledge. The railway project only demanded knowledge from utility experts when specifically asked and without providing a bigger picture of the project’s overall design which led them uncertain about what knowledge should be delivered.

In terms of creating a culture of inclusivity, the highway project ascribed importance to underground utilities by declaring them a priority in project organisation. This seems to explain the motivation of knowledgeable actors to share their knowledge with the design team. The airport and railway projects clearly showed a lack of an inclusive *project culture* in relation to underground utilities in the project organisation. The utility experts in these projects had the feeling that they were subsidiary to or forgotten in the process which resulted in a lack of motivation for these experts to share their knowledge.

Finally, the highway project showed a great deal of *trust* amongst the various actors within the design, which motivated utility experts to share their knowledge. Especially the way utility experts and owners trusted the manager responsible for the underground was apparent. The airport and railway project both had a lack of *trust* between actors knowledgeable of underground utilities and the designers and/or other project actors. The analysis of the three most distinctive knowledge governance mechanisms shows that these mechanisms try to integrate knowledge through motivation to share their knowledge.

Furthermore, the mechanism of allocation of *authority*, which is prerequisite for knowledge integration, shows that the airport and highway projects both contracted an engineering firm, which provided clarity in coordinating their knowledge. Both these projects had a manager who formally managed the contact with the engineering firm resulting in an authority that was primarily responsible for underground utilities. It was also striking that the conditioning manager in the highway project seemed to have a broader set of responsibilities than the project manager utilities, which facilitated a clearer coordination of the knowledge of utility experts and potentially facilitated a greater variety of knowledge. The authority in the railway project also had a utility expert who was responsible for the delivery of design products which were related to underground utilities, but there were multiple managers responsible for underground utilities, which complicated the integration of knowledge.

Table 5. Overview of the mechanisms contributing to knowledge integration.

Knowledge governance	Governance mechanism	Airport project	Rail project	Highway project
Formal	Project structure	M	M	M
	Allocation of authority	M	L	H
	Reward system	L	L	H
	Steering	H	H	M
Informal	Project network	M	L	H
	Project culture	L	L	H
	Trust	L	L	H

Bold rows are considered the most crucial on knowledge integration

The other mechanism prerequisite for knowledge integration shows that knowledge governance is supported by a *project network* that is based on continuity. To accomplish continuity in the project network, the highway project hired a utility expert for their design team who was knowledgeable in the region and had past experiences with working on this project. The project shaped a network by supporting the coordination between the actors who relied on their past working experiences. For example, the airport project had a network consisting of a utilities project manager and utility experts who had known each other for a long time. However, they were unfamiliar with the design team of the engineering firm and made coordination less smooth. The railway project lacked such a network of actors with long-standing relationships. Furthermore, this network lacked the systematic inclusion of utility owners. For example, the municipality, as permit provider, was only included in the project through a utility expert, which hampered coordination. Consequently, the utility expert was relatively isolated within the design team. These cluster of less influential mechanisms suggests that coordination is a prerequisite for knowledge integration between actors.

Notably, the airport and railway project had to *steer* heavily on the knowledge integration process. The steering was mostly aimed at the coordination between actors by strengthening the project network or adjusting the allocation of authority. Steering on coordination did facilitate a better knowledge integration, but it could not fully resolve the challenges that were present within the project. However, the coordination was not enough to fully facilitate the integration of knowledge of the underground. The highway project did mostly steer on motivation mechanisms, such as trust and culture by emphasizing the importance of individual project participants. This way of steering provided stability in the direction of the project and inspired ownership for project participants.

Discussion

This paper discussed the knowledge governance mechanisms of three large airport, rail and highway projects that contributed to the integration of knowledge on underground utilities. Our qualitative, interpretative research (Yanow and Schwartz-Shea 2015) showed that each project had their own knowledge governance approach, which resulted into various levels of knowledge integration. Based upon the findings we analysed three important knowledge governance

mechanism–reward system, trust and culture—which aim to motivate project participants to share knowledge. While each of these mechanisms was already identified in literature as an important mechanism (see i.e. Pemsel and Müller 2012, Huang *et al.* 2013), extant literature did not assess the mechanisms as a part of a collective. Additionally, our analysis suggests that the knowledge governance mechanisms network structure and allocation of authority are a prerequisite in coordinating knowledge between the different knowledge nodes. Finally, the findings show that steering was a stand-alone mechanism mainly trying to influence the coordination between actors to integrate knowledge. These findings results in a new framework on how to gauge the different types of formal and informal knowledge governance mechanisms in relation to each other and thereby contribute to the debate on knowledge governance in projects in two important ways.

Knowledge integration in large projects: governing an underground design

The first contribution is related to the value of analysing relationships between specific governance mechanisms that facilitate knowledge integration within projects. Until recently, scholars have most notably adopted a management perspective to study knowledge integration in projects (compare Styhre and Gluch 2010, Senaratne *et al.* 2017). In such a perspective, formal knowledge governance mechanisms are understood to be separated from informal knowledge governance mechanisms such as the network of and trust between project actors. Some studies try to overcome this separation by using a knowledge governance perspective, which bridges formal and informal mechanisms. For example, Tiwana (2009) analyses the dissemination of knowledge through information systems, while Pemsel *et al.* (2016) analyse strategies of managers in influencing project actors' interactions. In other example, Pemsel *et al.* (2014) employ a theoretical approach to unravel the relationship between formal and informal knowledge governance mechanisms. By empirically analysing the relationships between different knowledge governance mechanisms, we were able to advance our understanding of knowledge integration by providing more detail about what constitutes the dimensions of knowledge integration (as shown in Figure 2), which was called for by others (i.e. Pemsel and Wiewiora 2013).

To explain the relationships between the knowledge governance mechanisms that we have found,

we point towards the goal of what the mechanisms try to accomplish. For example, the combination of reward system, trust and culture were together considered to be the most fitted in the goal to integrate knowledge by motivating knowledgeable actors. Other studies may have clustered mechanisms differently. For example, Huang *et al.* (2013) considered project structure and culture as factors belonging to the same cohort. This difference can be explained as Huang *et al.* (2013) focussed solely on mechanisms influencing knowledge sharing, while our study focussed on knowledge integration. This explanation demonstrates that the goal of the governance, which could be knowledge integration, sharing, retaining, or learning, requires different combinations of governance mechanisms to effectively accomplish the goal.

Governance mechanisms to integrate knowledge in projects

Finally, the findings show that steering on the knowledge integration process is organized in two ways. Projects with a lesser degree of knowledge integration mostly steered on coordinating mechanisms. Although the coordination seemed to somewhat facilitate knowledge integration, it was unable to compensate for the absence of the motivating mechanisms that seem to be more influential in integrating knowledge. This is interesting because scholars often point to process management for steering the knowledge in a desired direction (Todorović *et al.* 2015, Pemsel *et al.* 2016). For example, Doloi (2013) emphasises the need for project managers to steer the project actor's awareness and position within the social environment in order to bringing their knowledge in line with project needs. The finding of Doloi (2013) points mostly towards steering on coordination, while this study suggests that steering on motivation might be just as important. Regardless of these observations from

previous studies, this study finds that process management aimed at motivation may be beneficial as well.

Conclusions

This study aimed to reveal the governance mechanisms that contribute to the integration of knowledge on underground utilities within large construction projects. The multiple case study was guided by the question *how do specific combinations of formal and informal knowledge governance mechanisms affect knowledge integration??* The findings suggests that some knowledge governance mechanisms have a stronger effect on the integration of knowledge in projects than others. Another crucial finding is the way we were able to reveal a connection between combinations of knowledge governance mechanisms to the dimensions of knowledge integration, as asked for by scholars (Huang *et al.* 2013, Asrar-ul-Haq and Anwar 2016).

This study's theoretical contribution to the debate on knowledge governance in projects (Foss *et al.* 2010, Demirkesen and Ozorhon 2017, Zahra *et al.* 2020) is two folded. First, this study contributes by showing the value to empirically analyse the relationship between different knowledge governance mechanisms. We were able to advance our understanding of knowledge integration by providing more detail about what constitutes the dimensions of knowledge integration (as shown in Figure 2), which was called for by others (i.e. Pemsel and Wiewiora 2013). To explain the relationships that we have found between the knowledge governance mechanisms, we point towards the goal of what the mechanisms try to accomplish (Huang *et al.* 2013). This opens up the debate about the use of specific types of mechanisms vis-à-vis its goal, e.g. knowledge retention, learning etc.

The second contribution reveals the link between different knowledge governance mechanisms and the hierarchy between mechanisms in affecting knowledge integration. The findings indicate that the combined mechanisms of reward system, project culture and trust seem to have a stronger effect on integrating knowledge in projects than the mechanisms project network and allocation of authority which seem to be more of a prerequisite in coordinating interactions to make integration possible. These insights unveil the a distinction between mechanisms but also conformity among mechanisms in integrating knowledge in projects (Hoetker and Mellewig 2009, Foss *et al.* 2010, Zahra *et al.* 2020). The clustering among the knowledge governance mechanisms is related to

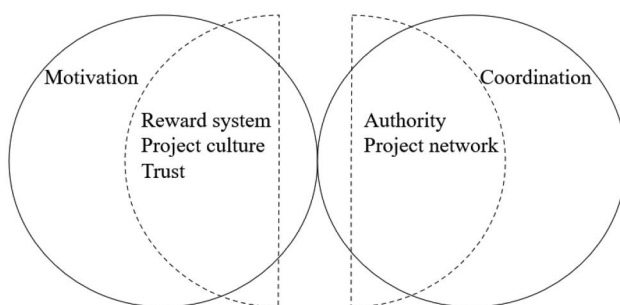


Figure 2. Empirical framework. The figure shows which formal and informal knowledge governance mechanism falls into which dimension.

the knowledge integration dimensions motivation and coordination. This observation sheds new light on the relationships between knowledge governance mechanisms and these dimensions, as asked for by others (i.e. Huang *et al.* 2013). Surprisingly, we contradict previous studies that emphasize the importance of project structure and process management in knowledge governance in projects (Pemsel *et al.* 2014, Demirkesen and Ozorhon 2017).

A major limitation of this study is that it cannot easily be generalised to other project contexts. Although similar contexts between the cases facilitated comparisons, the similarities and differences across the cases and the external validity of the findings might be problematic since the methodology remains a qualitative cross-sectional design. To further develop insights on the governance of knowledge integration, other (comparative and longitudinal) case studies in different project contexts are needed. New studies might focus on other types of specialised knowledge that require integration within a project, such as sustainability or safety. Finally, a practical contribution of this study concerns the management of knowledge integration. The found mechanisms expand the repertoire of project managers in managing knowledge integration. Project managers should carefully calculate the application of governance mechanisms based on their specific project environment, project phase and governance goal. They should adapt and learn through the process. The authors believe that examining knowledge integration from a knowledge governance perspective is a fruitful way of learning about projects.

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Appendix A.

	Airport project	Railway project	Highway project	Total
	(a)	(b)	(c)	
<i>Project organization</i>				
<i>Decision makers</i>				
1.1	Directors	3	1	5
1.2	Project managers	8	3	12
1.3	Stakeholder managers	2	1	4
1.4	Technical managers	2	1	3
<i>Experts</i>				
1.5	Utility experts	12	4	17
1.6	Safety experts	3	1	4
1.7	Designers	2	1	4
<i>Utility owners</i>				
2.1	Utility experts	1	1	1*
2.2	Representatives	2	2	2*
<i>Municipality</i>				
<i>Decision makers</i>				
3.1	Directors	1		1
<i>Experts</i>				
	Utility experts	1	1	1*
3.2	Permit providers	1	1	1*
3.3	Enforcer	2		2
3.4	Designers	1	1	2
<i>Contractor</i>				
<i>Experts</i>				
4.1	Utility experts	2	1	5
4.2	Safety experts	1		1
4.3	Designers	1	1	3
		36	23	14
				68

Note: In the category of utility owners and municipality, there are respondents (utility experts and representatives) that cover multiple projects.