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From Best Practices to Next Practices

Project-based learning in the development of large infrastructure

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From Best Practices to Next Practices: Project-based learning in the development of large infrastructure

Dissertation

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Keywords: Project-based learning, knowledge management, organizational learning, project management, large infrastructure project, co-creation, exploitative learning, explorative learning, collaboration.

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Summary

Over the last decades of development of knowledge management and organizational learning, there has been an increase in learning research within and across projects. Learning from past lessons in projects and preparing for the next project management practices is very important in large infrastructure projects. The autonomy of projects brings opportunities for generating new knowledge to solve problems but makes diffusing the knowledge between projects and even within stages of the project difficult. This poses a significant gap that may be negatively affecting practices. A clear and in-depth understanding of project-based learning is needed. The research aims to stimulate discussions and further debate about learning at the project level to identify and implement capabilities and structures that enable more efficient learning within and between projects in terms of value creation. To achieve the stated aim, the study attempts to answer the following main research question:

What is the role of learning, and how can learning be promoted in large infrastructure projects?

Q1. What is the state of the art of the current learning in project studies and practice?

Q2. How do large infrastructure projects carry out learning in good practices?

Q3. How can learning be promoted in large infrastructure projects?

The PhD research addresses this topic in the context of infrastructure projects. The research consists of a literature review of the existing studies on knowledge management and organizational learning in the project setting and an empirical overview of project case bases worldwide. Three case studies were carried out, respectively, in the MultiWaterWork program, and the Gaasperdammer tunnel project in the Netherlands, and Hong Kong–Zhuhai–Macau Bridge in China. The research investigated specific learning mechanisms that emerged, including value co-creation, exploitative learning in inter-organizational projects, and explorative learning in megaprojects. A cross-case analysis reveals five project-based learning principles to achieve project capabilities: 1) Owner commitment, 2) Social environment approach, 3) Collaboration vision, 4) Value orientation, and 5) Open mindset. It involves different learning modes (codification and personalization) and ambidexterity (explorative and exploitative learning) in different project phases (front-end and on-going execution) and in programs and large projects (including megaprojects).

We analyze and classify the research on "learning" in the "project" published in the leading project management, construction management, knowledge management, and general management journals. The research focuses on the project as a temporary organization and within contexts. Emerging research shows fragmented definitions and suggests a distinction between project-based learning and

organizational learning. Seeing projects as singular may inhibit learning from other projects. The concept of project-based learning is enriched by deepening insights on different dimensions, such as exploration and exploitation, codification, and personalization. It is revealed that social interaction may be more effective than database learning in the current project environment, and how to facilitate inter-project learning will gain more research attention. This research scans the state of the art and addresses the gap of project-based learning in the existing literature, which directs the position of project-based learning research.

Using the method of content analysis, this study provides a comprehensive overview of seven main project case bases set up by the academia or the market. It is found that the popularity of the project case base is increasing, with a majority emanating from Europe. Besides, some emerging issues mainly related to operation types, adopted methods, the scope of data collection and analysis, and limited access to project data, etc., are identified. The research then discussed the limited use of current project case bases. The project case base should not only be seen as a repository of explicit knowledge but more accurately seen as the product of tacit knowledge. More research on emphasizing the acquisition and disseminating of knowledge through social processes is recommended.

This research paid attention to activates and initiatives in large infrastructure projects that stimulate learning. It shows how learning is unfolded in three different cases and brings the three cases together.

The first case investigates what stakeholders do in co-creation sessions and how this contributes to the co-creation of value at the front end of programs. We used an action research approach combined with participant observation, document analysis, and interviews with participants to study stakeholder engagement in co-creation sessions at the front end of a Dutch infrastructure development program. The findings show that the client intended to realize a value (value-for-firm) that was competing with market partners' values. Engaging in co-creation sessions with the client, market partners, and knowledge partners co-created three sets of values (value-in-use) as follows: commercial, intellectual, and collaborative values. The findings contribute to the academic debate on value creation in programs with an in-depth understanding of co-creation sessions at the front end.

The second case analyses the exploitative learning process that occurred in the longest tunnel project in the Netherlands. Data were collected through archival documents, in-depth interviews, and site visits in the ethnographic research. The empirical findings indicate that exploitative learning is promoted with the help of the owner initiative. The most significant change that the exploitative learning process has led to is the change in mindset towards collaboration. Project culture is considered to be shaped by exploitative learning in the inter-organizational project. However, there is a gap between the knowledge transfer between the inter-organizational project management team and their parent organizations. The findings have practical implications for understanding learning in practical inter-organizational project

settings.

The third case draws upon the Hong Kong-Zhuhai-Macao Bridge (HZMB), a cross-sea link construction project, to study how the ability to explore was achieved and sustained. The findings indicate that the megaproject is more likely to increase complexity but might bring the value of more significant learning opportunities. Explorative learning is enacted through the complementary use of owner leadership, collaboration, external resources, and experiment. This research adds to our knowledge of how explorative learning works in practice and highlights its significance for the megaproject context.

A cross-case analysis follows and presents reflections. We show how learning is unfolded in three different cases. The empirical evidence gathered in this research forms five project-based learning principles: 1) Owner commitment, 2) Collaboration vision, 3) Social environment approach, 4) Value orientation, and 5) Open mindset. The study then focuses on the contribution of learning to achieve project capabilities. It is suggested that the critical role of learning in developing project capabilities should be on the future research agenda of infrastructure projects.

This research provides new insights and understanding into learning in the project setting in the built environment, adding its perspectives to knowledge management and organizational learning. We argue the social side of learning rather than the previous efforts on explicit and post-project knowledge. The finding rejects the position of knowledge management as a best practice toolkit for immediate use. It emphasizes that there is no pure copy-paste knowledge learned from one project to another. Social channels such as co-creation sessions are more useful for distributing highly context-specific knowledge. The most significant change that exploitative learning has led to is the change in mindset. Explorative learning is enacted through the complementary use of leadership, collaboration, global resources, and experiment. Co-creation practices contribute positively to exploitative and explorative learning. Primarily, we emphasize the role of owner, collaboration, social environment, value orientation, and mindset change. Measures and environment that is dialogical, open, and tolerant of uncertainty, are needed to foster learning. In this environment, the owner sets the tone for project participants to retain shared knowledge and trust, search, and use new knowledge. We collaborate to learn and learn to collaborate in projects' autonomy, which brings opportunities for generating new and innovative knowledge. We recognize that project-based learning and project capabilities lead to better business and project performance. This research underlines an essential capability for project management to develop, i.e., learning capabilities.

The research is expected to have important implications for project-based organizations, project managers, and academics in the infrastructure sector. It creates a dialogue between theory and practice to address the current infrastructure project management challenges and provides insights to inform potential solutions to project-based learning and understand the relationship between stakeholders. It

provides practical guidance for infrastructure project owners and contractors in their inter-organizational design and project-based learning at the front-end and execution phases of those projects.

Samenvatting

In de afgelopen decennia is er een toename geweest van leeronderzoek binnen en tussen projecten met betrekking tot de ontwikkeling van kennismanagement en het organisatieleren. Het kunnen leren vanuit lessen die zijn opgedaan in eerdere projecten is erg belangrijk om de volgende projectmanagement praktijken bij grote infrastructurele ontwikkelingsprojecten voor te kunnen bereiden. Doordat deze projecten autonoom functioneren, biedt het enerzijds kansen voor het genereren van nieuwe kennis waarmee problemen aangepakt kunnen worden. Maar anderzijds maakt het autonome karakter van dit soort projecten het juist moeilijker om kennis tussen projecten en zelfs binnen de verschillende fasen van het project te verspreiden. Deze ogenschijnlijke tegenstelling heeft een negatieve invloed op hoe leren in de praktijk kan worden toegepast. Dit vraagt om een duidelijk en diepgaand onderzoek van het begrip projectmatig leren. Het onderzoek heeft tot doel om de discussies over leren op projectniveau te stimuleren en daarmee de capaciteiten en structuren te identificeren die het efficiënter leren, in termen van waarde creatie, binnen en tussen projecten mogelijk maken en deze te implementeren. Om het gestelde doel te bereiken, zal deze studie op de volgende hoofdonderzoeksvraag in gaan:

‘Wat is de rol van leren in grote infrastructurele ontwikkelingsprojecten en hoe kan het leren hierbij worden verbeterd?

Hieruit volgen de volgende sub-vragen:

Vraag1. Wat is de stand van zaken van het leren in huidige projectstudies en in de praktijk?

Vraag2. Hoe wordt het leren bij grote infrastructurele ontwikkelingsprojecten vertaald naar goede praktijk voorbeelden?

Vraag3. Hoe kan leren in grote infrastructurele ontwikkelingsprojecten worden verbeterd?

Het doctoraatsonderzoek behandelt dit onderwerp in de context van infrastructurele ontwikkelingsprojecten. Het onderzoek bestaat uit een literatuuroverzicht van de bestaande studies over kennismanagement en organisatieleren in de projectomgeving en uit een empirisch overzicht van projectcases wereldwijd. Daarnaast zijn er drie casestudies uitgevoerd, respectievelijk met het MultiWaterWerk-programma, met het Gaasperdammer-tunnelproject, beiden lopend in Nederland, en met de Hong Kong-Zhuhai-Macau-brug in China. Het onderzoek behandelt specifieke leermechanismen die in deze cases naar voren kwamen, waaronder de waarde van co-creatie, het exploitatief leren in projecten tussen organisaties en het exploratief leren in megaprojecten. Uit een cross-case analyse komen vijf project gebaseerde leerprincipes naar voren om de project competenties te vergroten: 1) Betrokkenheid van de opdrachtgever, 2) Wijze van benadering van de sociale omgeving, 3)

Samenwerkingsvisie, 4) Waardeoriëntatie en 5) Open mentaliteit. Deze leerprincipes zijn gebaseerd op verschillende leermodi (codificatie en personalisatie) en op ambidexteriteit (exploratief en exploitatief leren) in verschillende projectfasen (front-end en lopende uitvoering) zowel in programma's als in grote projecten (inclusief megaprojecten).

De analyse en classificatie van dit onderzoek is gebaseerd op het "leren" in het "project" zoals dat is gepubliceerd in toonaangevende tijdschriften voor projectmanagement, bouwmanagement, kennismanagement en algemeen management. Het onderzoek richt zich op het project als tijdelijke organisatie en binnen contexten. Recent onderzoek laat zien dat definities over leren gefragmenteerd zijn en dat het suggereert dat er een onderscheid tussen leren op project basis en organisatorisch leren kan worden gemaakt. Het leren van andere projecten kan echter belemmerd worden door een project als een unieke entiteit te beschouwen. Het concept van leren op project basis wordt juist verrijkt door inzichten in de verschillende dimensies, zoals exploratie en exploitatie, codificatie en personalisatie te betrekken. Zo is gebleken dat sociale interactie in de huidige projectomgeving effectiever kan zijn dan het leren vanuit databases. Dit onderzoek start vanuit de huidige stand van zaken en gaat verder in op het gat die de bestaande literatuur achterlaat met betrekking tot projectmatig leren en de positie van projectmatig leeronderzoek.

Met behulp van de methode van content analyse wordt een uitgebreid overzicht gegeven van zeven belangrijke projecten die in de afgelopen periodedoor de academische wereld of de markt zijn opgezet. Hieruit blijkt dat vooral in Europa de populariteit van het gebruik van case-base in projecten toeneemt. Daarnaast laat dit overzicht zien dat er problemen ontstaan die voornamelijk verband houden met het type project, met de toegepaste methoden, met de reikwijdte van gegevens-verzameling en -analyse, en met de beperkte toegang tot projectgegevens. Het onderzoek laat vervolgens het beperkte gebruik van de huidige projectcases zien. De analyse laat zien dat de projectcase niet alleen als een opslagplaats van expliciete kennis moet worden gezien, maar meer als het product van zogenaamde stilzwijgende of latent aanwezige kennis. Meer onderzoek naar het verwerven en verspreiden van juist dit soort kennis via sociale processen wordt aanbevolen.

Dit onderzoek besteedt aandacht aan hoe leren in grote infrastructurele ontwikkelingsprojecten kan worden gestimuleerd door nieuwe initiatieven te starten en deze te activeren. In dit onderzoek worden drie casi behandeld waarmee inzichten worden verkregen hoe het leren zich binnen deze casi ontwikkelt.

De eerste casus onderzoekt wat stakeholders doen in co-creatiesessies en hoe dit bijdraagt aan de waarde vermeerdering van co-creatie aan de voorkant van programma's. We gebruikten een Actieonderzoek gecombineerd met participerende observaties, documentanalyse en interviews met de deelnemers om de betrokkenheid van belanghebbenden in co-creatiesessies aan de start van een Nederlands programma voor infrastructurele ontwikkeling te bestuderen. De analyse laten zien dat de opdrachtgever van plan

was om een waarde (“value-for-firm”) te realiseren die concurrerend was met de waarden van de marktpartijen. Door co-creatiesessies met de opdrachtgever, de marktpartijen en kennispartners op te starten werden drie sets van waarden (“value-in-use”) gecreëerd: commerciële waarde, intellectuele waarde en samenwerkingswaarden. Deze bevindingen dragen bij aan het academische debat over waarde creatie in programma's met een verdergaand begrip van hoe co-creatiesessies aan het begin van programma’s functioneren.

De tweede casus analyseert het exploitatief leerproces zoals dat in het langste tunnelproject van Nederland heeft plaatsgevonden. Gegevens werden verzameld via archiefdocumenten, via diepte-interviews en via locatiebezoeken als onderdeel van het etnografisch onderzoek. De empirische bevindingen geven aan dat door het nemen van initiatief van de eigenaar het exploitatief leren kan worden bevorderd. De belangrijkste verandering waartoe het exploitatief leerproces heeft geleid, is met name de mentaliteitsverandering die uiteindelijk nodig blijkt te zijn voor een goede samenwerking. Daarbij wordt verondersteld dat de projectcultuur in de interne organisatie door het exploitatief leren wordt gevormd. Echter de kennisoverdracht tussen projectteams die binnen een organisatie opereren en hun moederorganisatie is niet altijd goed geregeld. De uitkomsten uit deze cases geeft ons, vanuit een praktische invalshoek, inzichten om het leren in inter-organisatorische projectomgevingen beter te kunnen begrijpen.

In de derde casus wordt onderzocht hoe binnen het project exploratief leren werd bereikt en in stand werd gehouden. Deze casus betrof de Hong Kong-Zhuhai-Macao-brug (HZMB), een bouwproject voor verbindingen over de zee. De resultaten geven aan dat bij dit megaproject de complexiteit in eerste instantie weliswaar wordt vergroot, maar dat juist binnen deze complexiteit meer significante leermogelijkheden aanwezig zijn. Exploratief leren wordt uitgevoerd door het complementair gebruik van leiderschap van de opdrachtgever, van samenwerking, van externe middelen en van experimenten. Dit onderzoek draagt bij aan onze kennis over hoe exploratief leren in de praktijk werkt en benadrukt de betekenis ervan voor de megaproject context.

In het onderzoek wordt vervolgd met een cross-case analyse reflecties gepresenteerd. We laten zien hoe leren zich in vier verschillende gevallen ontvouwt.

Het empirische bewijs dat in dit onderzoek is verzameld, vormt vijf project gebaseerde leerprincipes: 1) Betrokkenheid van de opdrachtgever, 2) Visie op de samenwerking, 3) Betrekken van de sociale omgeving, 4) Waarde-oriëntatie en 5) Open mentaliteit. Het onderzoek richt zich vervolgens op de bijdrage van leren aan het bereiken van project capaciteiten. Er wordt aanbevolen dat voor het ontwikkelen hiervan er een cruciale rol voor leren is weggelegd en dat dit op de toekomstige onderzoeksagenda van infrastructurele ontwikkelingsprojecten dient te staan. Dit onderzoek biedt nieuwe inzichten in het leren in de projectomgeving van de gebouwde omgeving en voegt perspectieven

toe aan kennismanagement en organisatorisch leren. We onderstrepen het belang van de sociale kant van leren in plaats van de eerdere inspanningen op expliciete en post-projectkennis. Deze bevinding verwerpt de positie van kennismanagement om als een best practice toolkit direct binnen projecten te gebruiken. Het benadrukt dat er eigenlijk geen pure copy-paste-kennis is die van het ene project naar het andere kan worden overgeheveld. Sociale kanalen zoals co-creatiesessies zijn vele malen nuttiger om zeer context specifieke kennis te verspreiden. De belangrijkste verandering waartoe exploitatief leren heeft geleid, is de mentaliteitsverandering die nodig is. Exploratief leren wordt uitgevoerd door het complementair gebruik van leiderschap, samenwerking, wereldwijde middelen en uitvoeren en toepassen van experimenten. De praktijken van Co-creatie dragen positief bij aan exploitatief en exploratief leren. In de eerste plaats leggen we de nadruk op de rol van opdrachtgever, de samenwerking, de sociale omgeving, waardeoriëntatie en de mentaliteitsverandering. Om leren te bevorderen, heb je een omgeving nodig die open en tolerant is en waar een continue dialoog plaatsvindt. In deze omgeving zet de opdrachtgever de toon voor de projectdeelnemers om gedeelde kennis en vertrouwen te behouden, om nieuwe kennis te zoeken en deze te gebruiken en te delen. We werken samen om te leren en leren om samen te werken binnen de autonomie van projecten, wat kansen biedt voor het genereren van nieuwe en meer innovatieve kennis. We erkennen dat project gebaseerd leren en verhogen van de project capaciteiten uiteindelijk tot betere bedrijfs- en projectprestaties leiden. Dit onderzoek onderstreept het essentiële vermogen om voor projectmanagement verder te ontwikkelen: het leervermogen.

Resultaten van het onderzoek kunnen gebruikt worden door projectmatige organisaties, projectmanagers en academici in de infrastructuursector. Hierbij gaat het om het creëren van een dialoog tussen de theorie en de praktijk waarmee de huidige uitdagingen op het gebied van projectmanagement van de infrastructuur kan worden benoemd. Het biedt tevens inzichten die mogelijke oplossingen aandragen voor project gebaseerd leren en die de relatie tussen belanghebbenden beter leert te begrijpen. De uitkomsten van deze studie biedt een praktische begeleiding voor opdrachtgevers en aannemers van infrastructurele ontwikkelingsprojecten bij het opzetten van hun interne organisatie-ontwerp en hoe project gebaseerd te leren in de front-end- en de uitvoeringsfasen van projecten.

List of Abbreviations

AEC- Architecture, Engineering, and Construction

Chance2Sustain- Urban Chances, City Growth and the Sustainability Challenge

CII- Construction Industry Institute

CM- construction management

COB- Centrum Ondergronds Bouwen in Dutch, the Center for Building Underground

CPM- critical path method

ERP- Enterprise Resource Planning

EURAM- the European Academy of Management

GIPRN- Global Infrastructure Project Research Network

GPC- the Stanford Global Projects Center

GPO- Grote Projecten Organisatie in Dutch, the RWS department dealing with the Gaasperdammer tunnel project

GSP- the Gaasperdammer Tunnel, the longest tunnel on land in the Netherlands

HSE- Health, safety & environment

HZMB- Hong Kong–Zhuhai–Macau Bridge

IBC- Industry Benchmarking Consortium

ICB- Individual Competence Baseline

ICCPM- International Centre for Complex Project Management

IPA- Independent Project Analysis

IPAT- Infrastructure Project Assessment Tool

IPMA- International Project Management Association

IT- Information Technology

IXAS- the consortium of contractors in the GSP project

KM- Knowledge Management

MWW- MultiWaterWorks in Dutch, a large program for the replacement and renovation of 52 ship locks

NETLIPSE- the NETwork for the dissemination of knowledge on the management and organization of Large Infrastructure ProjectS in Europe

NSFC- National Natural Science Foundation of China

PM- Project Management

PMBoK- Project Management Body of Knowledge

PMI- Project Management Institute

PRINCE2- PRojects IN Controlled Environments

RCF- Reference Class Forecasting

RWS- Rijkswaterstaat in Dutch, the executive body of the Dutch Ministry of Infrastructure and Water Management

TEN-T- Trans European Transport Network

WBS- work breakdown structure

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Preamble

The only lesson humankind has learned from history is that human beings can't learn anything from history.

- Arnold Joseph Toynbee

Chapter 1 Introduction

Abstract

This chapter sets the scene for this PhD research. Infrastructure systems add essential value to society. The performance of many large infrastructure projects has long been seen as problematic all over the world. There has been an increase in the study of project-based learning. Learning within projects and between projects is one of the most critical aspects to improve the results of projects. The autonomy of projects brings opportunities for generating new knowledge to solve problems but makes diffusing the knowledge between projects and even within stages of the project difficult. There is a lack of seeking to develop theories linked to project-level learning and how an in-depth understanding of this type of learning can be gained. The main research question to be answered throughout this thesis is the role of learning and how learning can be promoted in large infrastructure projects.

1.1 Setting the scene

An efficient infrastructure system is vital for modern society from the economic, societal, and environmental point of view for any country. Adequate and sustainable infrastructure is a fundamental element for urban systems. Over the last decades, there has been a remarkable growth in the development of large infrastructure projects worldwide. McKinsey Global Institute predicted that the infrastructure investment would attract US$57 trillion between 2013 and 2030 (2013). The overall demand for today's infrastructure systems is increasing, and stricter requirements are imposed on service quality (Maparu and Mazumder, 2017; Poumanyvong et al., 2012; Wang et al., 2019). Rapidly changing environment, such as climate change, digital transformation, the renewal of existing assets, and a growing engagement of more dominant stakeholders, have greatly challenged the current infrastructure system (Connolly et al., 2020; Demuzere et al., 2014; Huétink et al., 2010; van Breugel, 2017; Vuorinen and Martinsuo, 2019).

Many researchers have underlined that large infrastructure projects are inherently complex and risky (Denicol et al., 2020; Fellows and Liu, 2012; Flyvbjerg, 2007). These projects are designed, executed, and influenced by different participants and stakeholders with different (sometimes conflicting) interests and within fuzzy boundaries. The increasingly complex external environment keeps impacting and changing projects both over time and in space. The focus for project management research in the construction industry is shifting from individual projects to the management of multiple projects and towards the relationships between projects and the broader organization (Martinsuo and Lehtonen, 2007).

Learning within projects and between projects is seen as one of the most critical aspects to improve the performance of projects (Keegan and Turner, 2001; Prencipe and Tell, 2001; Schindler and Eppler, 2003). As more and more infrastructure have to be built and maintained, the need to manage projects effectively and to respond to new opportunities requires the companies to learn from their internal and external experiences in different ways, to draw effectively on lessons learned to avoid making the same mistakes, and ultimately to achieve delivery more efficiently and sustainably. Project participants usually rely on previous experience and proven knowledge to create solutions and solve problems (Brady and Davies, 2004).

No two projects are identical. It is also one of the problems of projects that they are treated as constraint by their uniqueness or as once in a life-time opportunity (Almeida and Soares, 2014; Lindner and Wald, 2011). It is difficult to establish a set of principles to guarantee every project's successful accomplishment (Albert et al., 2017). In a recent NETLIPSE (Network for the dissemination of knowledge on the management and organization of large infrastructure projects in Europe) report reviewing ten years of managing large infrastructure projects in Europe from 2006 until 2016 (Staal-

Ong et al., 2016), project representatives were invited to score statements from eight project management themes if they were the case. Almost all the best practices formulated over a decade ago are still broadly recognized in practice today, although the world has changed considerably. The challenge is not to explore new best practices but rather to implement those best practices that we are already aware of. As an example, the low rated factors like stakeholder and contracting in 2006 have been improved visibly in the ten years since the first study. Nevertheless, the theme of knowledge & technology again scored the lowest after ten years (see Figure 1.1). Projects seem not to give enough attention to knowledge management policies or to exchange the use of research with wider projects (Disterer, 2002).

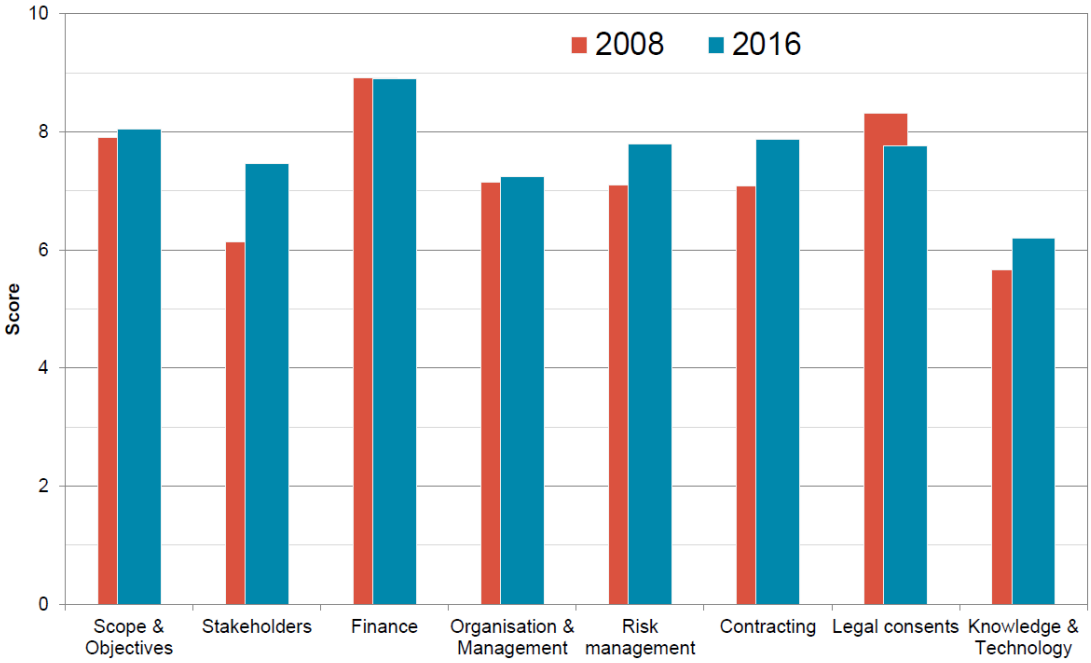

Figure 1.1 Score comparison (2008-2016) per theme from NETLIPSE

Learning is a widely used term but one with comprehensive definitions. Psychologists, linguists, and educators from various disciplines have studied the theme of learning broadly. This PhD research describes the process as "learning" rather than using other terms, in an attempt to help project managers see not just what has been done before but sharing what has been done by suggesting and eliciting what alternatives might be possible. It is in line with the perspective of self-regulated learning, where individuals learn proactively for themselves instead of reacting to an environmental stimulus (such as teaching) (O'Shea and Buckley, 2010). Compared with learning in schools, where the students make additions, expand their horizons, and choose their own direction, this research does subtractions and focuses on narrower but more effective areas.

1.2 Research problem

1.2.1 Poor infrastructure project performance

There is everlasting grumble about the performance of the large infrastructure projects globally, criticized as problematic already for a long time in terms of cost overruns, schedule delay, safety incidents, and quality defects all over the world (Bakker and De Kleijn, 2014; Flyvbjerg, Bent, Nils Bruzelius, 2003). Around two-thirds of megaprojects are viewed as failures (Hopewell, 2003; Merrow, 2011). One of the most notable cases in the US is known as the Boston Big Dig. This tunnel was initially estimated at $2.8 billion when work began in 1991 but was eventually completed in 2007, nine years behind schedule for $14.6 billion. Furthermore, these problems persist even in Germany, a nation traditionally regarded as representing the pinnacle of industrial efficiency. The country is suffering from some hugely delayed and over-budget public projects (Kostka and Fiedler, 2016). The Berlin Brandenburg Airport was initially scheduled to open in 2011 for €2.5 billion but has been delayed until 2020 at the cost of more than €9 billion. The Hamburg Opera House, meanwhile, was finally completed in 2016, six years late and costing €789 million – more than ten times the original budget. Another controversial public transport project, Stuttgart 21, has been dogged by a broad range of issues since the outset, including the rise in costs, delays, opposition from politicians and residents, and funding disputes.

The problem is related to the nature of the project-based construction organization (Scott and Davis, 2007). Distrust between the client and market, project-based collaboration with contractual arrangements and less strategic partnerships, and fragmented supply chains create enormous problems for the infrastructure industry actors and make it less integrated (Fellows and Liu, 2012; Kwak et al., 2009; Lloyd-Walker et al., 2014), fragmented actually.

1.2.2 Poor learning from the project to project

It is particularly attractive to capture the success stories from project-based work and to adapt them in the appropriate context to other projects and the broader organization (Kerzner, 2018). These best practices can significantly refine existing methods and offer new and flexible solutions to solve problems and complete tasks. It is also essential to learn from mistakes and avoid repeating them. These lessons learned can bring considerable benefits to future projects, and there are possibilities to increase the quality of the delivery and increase efficiency (Carrillo, 2005; McClory et al., 2017). Most project-based organizations recognize that project teams can achieve considerable improvement if best practices and lessons learned within and between projects can be made readily available and utilized. Project management professional bodies such as IPMA and PMI have made significant efforts to regularly improve, update and share relevant knowledge and good practices, including project management methods such as WBS (work breakdown structure) and CPM (critical path method).

However, infrastructure projects are still notoriously hard to manage. The poor delivery performance

has been criticized for decades, slow learning or less learning is a common situation and an inherent problem in the project context (Flyvbjerg et al., 2002; Hertogh et al., 2008). History shows that still many organizations fail to acquire, store, share, and transfer knowledge from projects to their organization institutionally. The problem can be linked to the nature of organizing (large) projects. Flyvbjerg (2016) pointed out that uniqueness bias is one of the main factors that decision-makers tend to overlook. Planners and managers often rely on non-standard technology and design to deliver megaprojects, making the projects singular and difficult compared with the past and other projects. It makes proactive learning from history and experience more difficult (Söderlund et al., 2017).

The question arises if the project team can share these experiences or lessons learned with their clients and supply chain partners. The challenge is not a lack of knowledge. In fact, the point is that there is more of it than is utilized, but to structure the learning in the right way to benefit from it. It remains unclear how to systematically disseminate and absorb learning as we move from project to project, working with different partners (Cooper et al., 2002). Among large infrastructure projects, achieving learning widely seems far less satisfactory. The function of knowledge management is challenged by current project management practices as temporary forms of organizing (Lindner and Wald, 2011). In many new projects, new teams are created, and much of the same "lost" knowledge then has to be re-acquired (Argyris and Schön, 1996). "Reinventing the wheel" happens far more on each project than learning and benefitting from the experiences of previous and other projects, which wastes both time and money.

1.2.3 Barriers preventing learning in and from projects

Although construction projects have been emphasized for their unique characteristics, the essentials are still repeated from project to project (World Economic Forum, 2016). The construction processes, labor division, team skills, standard materials, equipment, etc., used in different projects are similar. This provides the opportunity for the reuse of knowledge from one project to subsequent projects. If learning in and from projects has been recognized as an issue, why do project teams not put in place mechanisms to stimulate learning? Why is learning within and between large infrastructure projects a complex reality?

There are several challenges associated with learning from projects. The problem of learning within projects and between projects can be characterized into the following three domains: cultural/institutional domain, individual/social domain, and technical/product. We identified the following barriers during our exploratory interviews and literature studies (Scarbrough et al., 2004; Schindler and Eppler, 2003).

1.2.3.1 Cultural/ Institutional

The AEC (architecture, engineering, and construction) industry is centered on projects with many actors such as clients, designers, contractors, consultants, suppliers of equipment and materials, and asset

managers. The cultural/institutional domain includes the following aspects that are external and cannot be managed.

Project-based collaboration

There is a structure in which parties enter into a relationship for a specific project on a contract basis. Decision-making, planning, design, execution, and management of projects are typically developed and implemented by multiple public agencies and private market parties with conflicting interests. This ensures that knowledge is spread over numerous parties. The decentralized nature of the above organizations involved in projects makes the knowledge transfer more complicated (Eriksson, 2013).

A new project commences every time with varying design and procurement requirements, political and environmental conditions, client and contractor' experience, and expertise (Love et al., 2019). When the project is completed, the project team disperses. This makes discontinuous members suffer from a "knowledge loss" phenomenon. On the one hand, it leads to the causal ambiguity of knowledge (Lippman and Rumelt, 1982) potentially emerging from the project. On the other hand, it leaves a few people who can understand and grasp the project knowledge of the whole project. The internal stickiness of knowledge makes its transfer into the next project much more challenging (Szulanski, 1996). There is a danger that the wheel will be reinvented over and over again.

The inertia of existing processes and methods

Projects are characterized by tight project scope and control over time and money. It is experienced as oppressive as a result of which innovations have little chance. It is indicated that project-specific innovations arise mainly from individuals who are committed to an idea. These individual innovation actions are often not transferred to other projects because learning and development are not institutionalized (Scarbrough et al., 2004). Most learning and inspirations occur accidentally on the job; however, support for recording these experiences and support for dissemination is limited (Savelsbergh et al., 2016). Most project organizations face an organizational capability bottleneck due to the lack of an effective organizational learning mechanism (Buttler, 2016).

1.2.3.2 Individual/social

In the context of construction, there is a lack of motivation to share knowledge. The individual/social domain includes the following aspects that can be managed, but participants are unwilling to do so.

Insufficient political or public responsibilities

No mature routines have been agreed upon by all project participants to address knowledge sharing (Bektas, 2013). There are neither contractual requirements that assign a role or function in learning or knowledge management in projects nor a fixed part of the internal owner's assignment for the use and

transfer of knowledge from and to other projects. Knowledge reuse is barely a part of the established process. Project teams do not get a learning assignment. Therefore, they do not find the time to make an effort to capture and submit lessons and share their experiences or do not see it as a prioritized issue as project teams have no obligation or incentive to do it (Landaeta, 2008). The result-oriented culture leads to no time spent on learning. The absence of a person responsible for the process makes no one summarize the project's knowledge gains and losses from a holistic view.

Distrust between parties

Construction projects are mainly based on price competition and contractual arrangements. The inherent tensions and conflicts between owners and suppliers (Barlow and Jashapara, 1998) and competitors make project teams reluctant to share information. They tend to deliberately withhold information from clients or supply partners so that no images of inferior performance will be portrayed. They tend to adopts a mini-Machiavellian leadership and keep secrets (Argyris, 1976; Love et al., 2019). The hostile culture resists innovation and tends to emphasize the uniqueness and complexity of individual projects. The whole industry identified the issue; however, no applicable and effective measures have been found and/or taken until now.

Error prevention

While it was acknowledged that past failures could offer useful lessons learned to avoid making mistakes again, it seems difficult to obtain an accurate and detailed count of them (Love et al., 2019). To ask project teams to share their positive experiences and successes is not tricky; project team members find it hard to share bad experiences and are not willing to report mistakes. In line with the industry's emphasis on the lowest cost, there is a perception of intolerance of mistakes. Psychological insecurity reduces the beneficial potential for learning (Love et al., 2019). Lessons learned sessions could be enculturated as punitive (Julian, 2008). Reluctance to share negative experiences can be attributed to the fear that they might be judged and evaluated as less-performing project managers, which may potentially influence their reputation. "Bad news travels fast and good news never." A strict focus on error prevention and a tendency to blame within project-related practices can create a negative mindset toward reflecting errors and sharing experiences.

1.2.3.3 Technical/product

There is a lack of effective mechanisms to capture and store knowledge from past projects (Abdul-Rahman et al., 2011; Williams, 2008). The technical/product domain includes the following aspects that can be managed but which are technically very challenging.

Knowledge repositories

The knowledge repositories, project databases, or project case bases are a structural way to share a helicopter view on the various projects and measure project progress and performance by steering on inter-project learning. Compared with commonly used ERP (Enterprise Resource Planning) systems adopted in the manufacturing industry, it is hard to trace and record the data flow consistently and reliably in construction projects. The relatively large sizes and the complex nature of infrastructure project implementations have made it difficult to carry out rigorous statistical analyses of the project performance. The established processes and procedures for capturing and sharing lessons learned are cumbersome and rely on fragmented information scattered in paper-based documents (Love et al., 2019). What is worse, existing project databases collect their data in their ways and do not share information.

Psychological distance

Project team members often feel that they cannot directly adopt the lessons learned from other projects due to geographical and social gaps with different political, legal, economic, and cultural environmental conditions. Construction projects often take a long time to complete, which leads to lag between causes and effects of accidents and measures taken. From the perspective of risk management, project participants need to understand “black swans” and “white elephants”. This makes it challenging to translate this knowledge into a new project, working with other parties.

1.3 Research gaps

First, there is ambiguity among project-based learning, knowledge management, and organizational learning. They are often used interchangeably with much confusion (King and Ko, 2001). Knowledge management and organizational learning are similar in some ways but have different aims (Irani et al., 2009). The classic literature on knowledge management has focused on techniques and methodologies for codifying knowledge and making it available to organizations. Organizational learning aims to manage and utilize intellectual assets by creating organizational rules and processes (Argyris and Schön, 1997; Brown and Duguid, 1991; Senge, 1990). It focuses on a firm's capability to adapt to changing knowledge pressures (Irani et al., 2009). It seems the theories of knowledge management, organizational learning, and project-based learning have been established, respectively, and there are overlaps between all three concepts. It remains unclear how they are interacting with each other in practice.

Unlike some manufactured products that can be made automatically, projects are characterized by time-bound interaction with different parties, non-repeatable activity, and one-off tasks (Brookes, 2013; Wenger and Snyder, 2000). Project-based learning is thus influenced by temporal externalities (Eltigani et al., 2020). It is promulgated that project-based organizations and their projects can utilize organizational learning as a theoretical foundation to bolster their performance and productivity. Project-based learning has received growing attention within extant and generic theories of organizational learning. However, the origin of the organizational learning theory mainly stems from routine-based

organizations, not temporary projects. The experiments in the 1990s to develop a knowledge management model, framework, or database have largely proven to be futile. Project-based learning finds itself challenging with a short-term competitive relationship and without repeat collaboration between project participants (Cao and Wang, 2014).

Academic research and practice have been increasingly centered on the broad umbrella term of learning, reflecting the desire to understand the ability of individuals, teams, projects, organizations, networks (industries or supply chains) to improve. Many learning studies adopt the dominant approach based on an individual cognitive view, including changes in perceptions, attitudes, and behaviors. We are talking about learning at levels higher than the individual. It calls for the theoretical position of project-based learning at the project level instead of the team level (Savelsbergh, 2010; Senaratne and Malewana, 2011; Swan et al., 2010). A project is temporary, fluid, interrupted, and distributed. The definition of a "team" emphasizes characteristics of shared identity and continued commitment to team members. Role identities are often not clearly defined to members of the project as not all of them belong to an identified team (Scarbrough and Swan, 2009).

Different forms of learning, by different actors, in different networks, and at different levels, take place with different aims. Much is being done at the organization level or the team level. However, the core issue of learning among infrastructure projects is still not being addressed. It typically lacks the community-building effects (Swan et al., 2010). There is a lack of seeking to develop theories linked to project-level learning and how we can gain an in-depth understanding of this type of learning. This PhD research aims to investigate learning from "doing" projects (Eltigani et al., 2020; Newell and Edelman, 2008).

1.4 Research aim and objectives

One of the main challenges of present-day project management is learning from completed and on-going, successful and unsuccessful projects. Projects can use the best practices and obtain the choices which suit their circumstances and operational contexts.

Bringing all these concepts together, the research aims to stimulate discussions and further debate about learning at the project level to identify and implement capabilities and structures that enable more efficient learning within and between projects in terms of value creation. Learning itself consists of both the learning process and learning products (Gerlak and Heikkila, 2011). This research focuses on the learning process as a set of actions rather than the learning products referring to new shared ideas, skills, knowledge, and technology as the outcome of the learning process. The focus of the PhD research will be on the organizational process and multi-actor network in the project setting.

Under this aim, the specific objectives are threefold:

1, investigate the current learning practice in infrastructure projects and identify existing barriers for project-based learning.

2, get assess to how project-based learning is carried out in different project phases (front-end and on-going execution) and large infrastructure programs and megaprojects.

3, provide suggestions to the project-based firms to enhance learning for the execution of their future large infrastructure projects.

1.5 Research question

To achieve the stated aim, the study attempts to answer the following main research question:

What is the role of learning, and how can learning be promoted in large infrastructure projects?

The main research question can be split into several sub-questions. Answering the sub-questions will lead to the answer to the main question. In line with grounded theory, this research stated with a broad sub-question and, in a way, reflected a problem-centered perspective. The research process will then generate the following sub-questions (Birks and Mills, 2015). Therefore, this research is organized around three sub-research questions that build upon one another:

1, Problem analysis

Q1. What is the state of the art of the current learning in project studies and practice?

2, Empirical investigation

Q2. How is learning achieved at the level of the large infrastructure projects?

3, Synthesis

Q3. How can learning be promoted in large infrastructure projects?

1.6 Theoretical lens

A unified theory of project management does not exist (Smyth and Morris, 2007). Therefore, there is no single theory of project-based learning. The contingency perspective is more meaningful than the universalistic perspective. The thesis agrees with Söderlund and Maylor (2012) that much attention of learning has been on the techniques, planning methods, and formalities of project management, and nurturing the soft skills deserves more time and effort. The thesis positions itself into the Behaviour School and Relationship School in the standing of project management in the academies (Söderlund, 2011). The former considers the feature of projects as "temporary organizations" and investigates the

dynamic nature and process of projects' learning behavior. In contrast, the latter draws on the inter-organizational environment and its social construction. Therefore, our primary research approach includes inductive and descriptive research (e.g., case studies) with limited interest in formulating and testing hypotheses. The empirical context of infrastructure and construction can provide pertinent and sufficient data and ideas.

The research determines three dominant concepts that characterize the meaning of project-based learning. First, it is guided by a social constructivist epistemology and informed by situated learning theory (Sense, 2013). The second one is to depict project-based learning as a process of knowledge management. This view helps bring about changes in the way projects are delivered, using a range of more collaborative but innovative approaches. The third one views project-based learning as a sub-concept of organizational learning. This view emphasizes that project-based learning can bring together project actors and achieve sustainable and collaborative performance improvement in the construction industry.

Interpretative methodologies seek particular explanations, while positivism seeks general explanations. We took an interpretative perspective to explore the plural facet of single cases (Geraldi and Söderlund, 2018), which seek implications for the actuality of project-based learning. The interpretative methodology embraces the grounded theory, ethnography, action research, and other case-based methods to understand phenomena. Then these single cases are seen as similar and comparable in search of verified rules.

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Chapter 2 Research Methodology

Abstract

In this chapter, the research philosophy, strategy, design, and methods are developed. A qualitative approach is chosen for this research in line with the philosophical position supported by large infrastructure projects' complex context. The research design consists of literature and empirical review, action research, ethnographic research, inductive research, and cross-case analysis. The research is described in three phases. The first phase mainly consists of a literature study and an empirical overview. The second phase entails exploratory and semi-structured interviews, site and participant observation, focus group discussion, and the close reading of archival documents and other sources. Content and thematic analysis were completed to organize information into the main research question categories. The PhD research started with the within-case analysis to identify new phenomena and their implications within a single case. The third stage proceeded to compare across the cases to conclude cross-case patterns of project-based learning.

2.1 Research positioning and strategies

All research has philosophical assumptions about reality (ontology) and knowledge (epistemology) as the foundation. There is a lack of the selection and application of research epistemology and methodology in many academic journal papers (Smyth and Morris, 2007), not to mention PhD research at technology universities, as I observed.

Construction management and engineering research are concerned with organizing and managing the design, realization, and operating processes of physical building and infrastructure objects. Research on knowledge management and organizational learning in general, and learning in and from projects in particular, deals with both the physical and the social world. Among the current research, we can distinguish two directions (Koskela, 2017): 1) How to design, analyze, and operate materials, machines, technologies, and construction methods; lies in the technical domain of material reality. 2) How to plan, organize, and control business organizations' resources and activities; lies in the domain of the mind. The line of reasoning and result are fundamentally different. The former strives to create and develop new engineering solutions, while the latter is directed towards acquiring new knowledge of the world as the available knowledge is not sufficiently aligned to the empirical facts. This thesis chooses the second type, the research-oriented management approach, to understand (problem analysis) and focus on human organization processes, resulting in new knowledge.

All research should be aware of the different philosophical positions that influence how the research will proceed before attempting to conduct the research. There are two different conventional paradigms regarding how management research should be performed: positivism and interpretivism (Guba and Lincoln, 1994). Positivism follows a realist ontology and assumes that absolute mechanisms drive reality, and knowledge can be described through law-like generalizations. Interpretivism (also called social constructionism) believes that people experience physical and social reality in different ways. Positivism stands in the empirical form that behaviors and activities can be observed, while interpretivism believes in the basic form that a human interprets experiences in various organizational contexts (Mingers, 2004). They are extreme positions at either end of a continuum. This thesis indicates that complexity exists within the organizational and social environment in the project setting, for which there are no hypotheses to be formulated and tested. The research should allow us to gain different perspectives and a better understanding of the particular project context. It also attempts to identify underlying patterns from the inductive theory building approach. This research situates itself between positivism and interpretivism paradigms. Critical realism is a combination of positivism and interpretivism as the third paradigm (Easton, 2010) that forms the foundation for this research.

Critical realism argues that social phenomena and the researcher's interpretation exist independently (Sayer, 1992). Critical realism's fundament is that the objective world exists, but our knowledge about

the world is subjective (Bechara and Van de Ven, 2011). It believes that reality is viewed as complex, and we are all biased. Therefore, to achieve a better and accurate understanding of what happens in reality, we have to rely on multiple sources of evidence. The aim is not to make general predictions and claims but to demonstrate various possible explanations of the underlying patterns.

Therefore, the thesis is a management and organization-based study. The aim is to suggest new ways in the practice of understanding complex phenomena and facilitate the learning process in large infrastructure projects. The basic premise is that the practitioners must construct knowledge in their own minds. Most notably, they are not passive vessels filled with knowledge but primary agents in their own learning.

As the research goals are to develop theoretical understanding holistically from the informants' perspective and set change in motion to solve practical problems, the methodology uses qualitative methods. A qualitative approach enables the development of critical aspects related to the phenomena of interest. It aims to describe complex phenomena situated and embedded in specific contexts (projects in this research) and is suitable for studying a limited number of cases in depth (Eltigani et al., 2020). It can also yield a much more vibrant and more detailed picture than a quantitative approach (Creswell and Creswell, 2017). Quantitative studies are mostly carried out in deductive methods and pay more attention to knowledge verification. Hertogh and Westerveld (2010) emphasized the significant challenge to establish general rules or basic assumptions by statistical evidence when studying the complex large infrastructure projects with multiple variables influencing each other. More acceptable and well-developed theories on managing complexity and organizing multi-actor practices such as project-based learning are more likely to comprise heuristics or rules of thumb other than algorithms to measure and predict. This research mostly adopts inductive methods and focuses on the discovery of new knowledge. The survey objects, which are individuals and organizations, are placed as a whole rather than variables separated in research for quantitative analysis. We should not regard the accurate prediction of the future as the (only) sign of a good theory. In fact, the thesis provides inspiration rather than answers.

2.2 Research design

The PhD research will answer the research question through a qualitative theory-building approach consisting of literature and empirical review, action research, ethnographic research, inductive research, and cross-case analysis. The research chooses to implement a qualitative and inductive research design that would enable revelatory yet rigorous analysis (Eisenhardt et al., 2016; Gioia et al., 2013) of the projects' organizational practices. Van Marrewijk and Dessing argued to apply sound theory and rigorous research methods to advance relevant knowledge and impact crucially project management practices (2019). The research involves both practitioners and academics and also built good relationships with

informants. It is being advocated to bridge the knowledge gap between academic scholars and project practitioners when gaining in-depth insights from close participation and engagement with the research informants (Bartunek, 2007; Söderlund and Maylor, 2012). **Figure 2.1** illustrates the research design in three stages. The following subsections will explicate how different methods are undertaken in the research, mainly in the case study and synthesis stages. More details can be found in sections of data collection and data analysis.

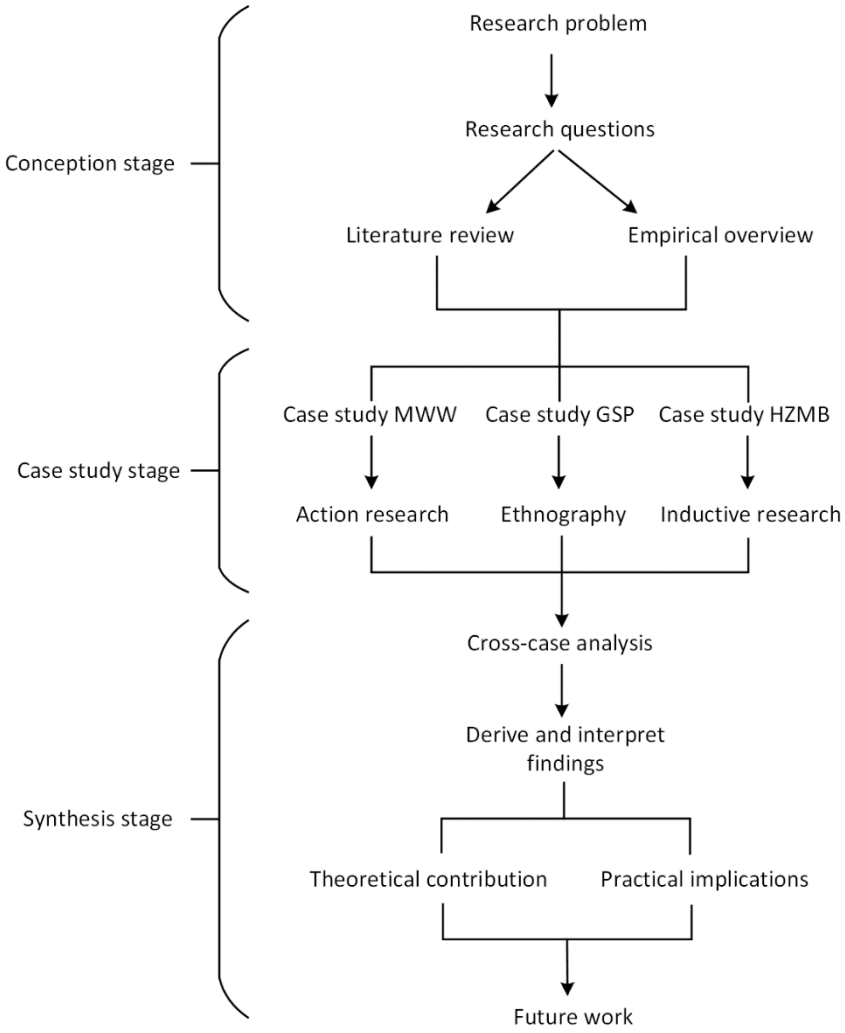

Figure 2.1 Research design

2.2.1 Conception

The conception stage is exploratory to define the focus of the research. It consists of a literature review and fieldwork performed in parallel. The systematic literature study is undertaken in Chapter 3 to summarize project-based learning research characteristics, including theoretical angles and levels and potential future trends. The fieldwork in Chapter 4 is an explorative pilot study aiming to gain a better understanding of practical orientation and perception. This is conducted by carefully reading leading

publications, conducting exploratory interviews with representative informants, attending workshops, and visiting the sites. Consulted information sources include Airport Architecture Anatomy at the University of Florence, Innovation Airport at Delft University of Technology, and NSFC (National Natural Science Foundation of China) project “Research on Theory, Method and Application Innovation of Major Infrastructure Engineering Management in China." This information was only used as a background context, not for the analysis. This stage helps confirm the problem formulation and research questions are relevant for research and allows the subsequent phases to focus on the project context, especially the social element.

2.2.2 Case studies

Case study research is a research method that focuses on in-depth empirical investigation and analysis of phenomena in their real-life context (Yin, 1984). It is an adequate research strategy when dealing with a complex situation, and the boundaries between phenomenon and context cannot be seen. The approach fits the interpretative and qualitative nature of this research, and it is suitable to study complex phenomena (Klein and Myers, 1999) in the large infrastructure project contexts. The case study method can open the "black box" of how interventions and expected outcomes are linked. This approach is different from the experiment to obtain results with a high level of certainty. Still, it can help pick valuable elements apart, clarify and interpret, and understand what is going on in these very complex situations. Many popular modern management theories, such as Core Competence of Enterprise, Balanced Score Card, Business Process Reengineering, are derived from case studies.

The researcher took advantage of evidence from three single case studies (the MultiWaterWork program in Chapter 5, Gaasperdammer tunnel project in Chapter 6 both in the Netherlands and Hong Kong–Zhuhai–Macau Bridge in China in Chapter 7) to explore the learning process in large infrastructure projects and programs with data sources including literature, archives, interviews, (participant) observations, and focus group discussions (Yin, 1984). First-hand data collected directly by the researcher, and second-hand data from other sources (commercial and government agencies, marketing research firms, digital databases, etc.) were collected. Multiple cases were used as the cross-case analysis approach can augment external validity and create a more robust and testable theory than a single case (Eisenhardt and Graebner, 2007; Haj-Yahia, 1998). After three single case studies, the researcher carried out a cross-case analysis to make the conclusion compelling. The acknowledgment underpins our reasoning that management and organization studies should focus on outliers rather than averages (McKelvey, 2006) in order to generate useful and insightful research outcomes.

2.2.3 Action research

Chapter 5 adopted the action research methodology. This research defines action research as a dynamic process concerned with developing practical knowing grounded in a participatory worldview (Kemmis,

2006). Action research challenges the traditional research typified to focus on reflective knowledge produced in outsiders' view (Torbert, 1991). Action research aims to empower the stakeholders in an engagement process to develop a shared understanding of the research topic (Kemmis, 2006).

Action research is one of engaged scholarship forms in project studies that directly addresses the problems by responding to the immediacy required by practices and the society (van Marrewijk and Dessing, 2019). The advantages of action research are the high-quality insights gained from close participation in and engagement with the researched projects. Our research team consisted of both practitioners and academics. The practitioners actively participated in the project and program management. Action research scholars perceive knowledge development as a mutual process dominated by engagement and collaborative relationships (Delhi, 2003). Over time, action research has been established as a set of practices through which researchers identify with the researched and through which analysis is made contextual (Reason and Bradbury, 2008). Finally, encouraging real participation, building relationships with informants, and acknowledging and sharing power with them are needed to establish credible accounts.

Our research team consisted of members from the program management team and participants of co-creation sessions to implement action research in different roles, and an outsider researcher to address the limitations of action research in the risks of the researchers' over-engagement with the field and the sympathetic interpretation of research findings. The insider researchers and the outsider researcher went through all of the reports, interview data, and observational notes, which helped write the chapter with more methodological rigor.

2.2.4 Ethnography

Initially developed in social anthropology to observe radically varied cultures, ethnography is developed as a qualitative method for collecting rich and complex social data (Fine et al., 2009). It allows various qualitative methods to study organizations, cultures, daily practices, and groups of actors (Schwandt, 1996). An ethnographic approach is chosen in Chapter 6 because of its attention to complexities that cannot be foreseen beforehand. Our research team consisted of a master student engaged as an intern to collect data, consultants offering recommendations to the project team and observers. We kept in close contact and often discussed in the site office during the process. The contribution of ethnographic studies is evidenced by the small but growing number of scholars using ethnography as a methodological approach in studying construction projects (Phelps and Horman, 2010; van Marrewijk et al., 2016). In this thesis, ethnographic research is evidenced to analyze the actors, daily practices, and social situations in projects (van Marrewijk et al., 2016). Combining the qualitative methods entails participant observation, interviews, and the close reading of documents or other sources (Sierk et al., 2009). It is a methodology apt to study organizational practices that are not immediately visible or observable. It aims to get an in-depth understanding of the often underlying or implicit aspects of specific (organizational)

cultures (Schwartz-Shea and Yanow, 2013; Sierk et al., 2009).

2.3 Data collection

Glaser and Strauss (2017) claimed the various procedures to build grounded theory from qualitative data. This research focuses on developing heuristics and principles based on collecting and analyzing in-depth empirical data from real cases. The combination of multiple data collection methods entails exploratory and semi-structured interviews, site and participant observation, focus group discussion, and the close reading of archival documents or other sources (Sierk et al., 2009). It proceeds in an inductive and exploratory manner (Siggelkow, 2007). There is sufficient inside evidence accessible to draw a good picture of what happened. A questionnaire-based upon the preliminary findings was designed and sent to all informants. Unfortunately, only a small number of informants accessed the online questionnaire, of which only a few were potentially usable. Therefore, the research did not use this information for the analysis, only as background information. These methods will be discussed in the following sections.

2.3.1 Archival documents/desk research

The researcher got access to the archival documents, mainly including archival project logs, reports and books, and online media from official and academic websites, to gain a general understanding through desk research. It is the first step of the three case studies. This information was used to prepare the interview protocol and understand the history of the project. The thesis does not guarantee the archival documents represent an exhaustive list in each case, but they are sufficiently representative for responding to our research questions.

In the MWW program case, the researcher collected the data from the government Internet portal and the official website, including the minutes and presentation slides, the interim versions and final versions of reports. In this way, detailed documents were collected, half of which were lengthy reports based on a large number of interviews and detailed information about critical events in the MWW program.

Two books published as deliverables in the GSP project case gave a comprehensive insight into how the exploitative learning process has been intended and how it has been put into practice in the project. The RWS and IXAS project team members interviewed were all involved in the making of both books.

The researcher could access an internal project magazine named "HZMB Bridge" run by the HZMB Authority. The magazine has been compiled six times a year from 2011 to 2017. All articles in the magazine were stored and categorized in a database that enabled searches for keywords and topics, which facilitated the new empirical analysis.

2.3.2 Interviews

The interviews are one of the most essential information sources (Duryan et al., 2012) due to their

insightfulness and the possibility of gaining rich data in case study research (Yin, 1984). Interviews have the potential to dig out critical incidents from the informants' hidden experience, and they allow the researcher to ask to follow up questions until clarity in reasoning is reached. Interviews offer in-depth and complementary perspectives from various participants to cross-check for specific issues and mitigate potential biases of the single and second-hand information sources, enriching our understanding of the phenomena and topics.

Informants can be very valuable for understanding and interpreting research findings (Yanow and Schwartz-Shea, 2015). The purposive selection of samples is essential in qualitative research (Miles and Huberman, 1994; Schwandt, 1996). The primary contacts helped identify and get approval for people to be interviewed.

In the three case studies of the thesis, exploratory interviews were executed to reflect on the field and the observations. Based upon all the preliminary findings, a semi-structured interview list was designed and tested with the informants. Semi-structured interviews provide the freedom to explore the informants' ideas and perceptions in a conversational tone and contain fixed topics and predetermined questions that can be compiled to obtain a certain level of standardization (O'Reilly, 2004). Informants were asked to reflect on how they engaged in and their experiences with the related projects' learning processes. Questions about informants' behaviors, events, context, opinions, and feelings were asked (Patton, 1987). Key actors and their organizational structures were then delineated. The interviews' interpretation was checked with the informants as a form of "member-checking" (Yanow, 2005).

2.3.3 Participant observation

Observation, particularly participant observation, has been widely adopted under the umbrella of ethnographic methods as a qualitative data collection method. It enables the researcher to systematically describe existing situations, including behaviors, events, and artifacts in the social setting (Erlandson et al., 1993).

The researcher participated in the projects' daily and routine activities as a careful observer and a good listener. During the process, the researcher established rapport within the community while observing their behaviors and activities in order to be immersed in the project to understand what is going on (Fine, 2003). For example, the researcher participated in the first stream of the front end of the MWW program, helping to address and collect (inter)national studies on lock designing, and participated in the co-creation sessions in the second stream. All observations and reflections were noted and worked out. Another example is that the researcher supervised a master student who acted as an intern for half a year to help the project parties to improve their learning trajectory.

2.3.4 Focus group discussion

Focus group discussion is a qualitative data collection approach where the researcher assembles a group of individuals to discuss a specific topic through a moderated interaction (Morgan, 1996). It is different from group interviews because the researcher adopts the role of a facilitator or a moderator in the group discussion between informants and is not an exchange between the researcher and the informants (Parker and Tritter, 2006). The purpose of the focus group discussion in the thesis is to confirm the interviews, participant observation, and document analysis findings.

For example, two focus group discussions were arranged separately at TU Delft in the Netherlands, involving more than ten representatives from the general contractor, consultants, and the HZMB Authority in Zhuhai, China (involving five representatives from the owner and the consultants). The focus group discussion allowed the informants to share their experiences and opinions on the topic of learning on a megaproject.

2.3.5 Triangulation

How can we avoid the qualitative data being influenced by our preconceptions about the phenomena we are studying? Triangulation is used to overcome the limitation of the sympathetic interpretation of research findings (Yanow and Schwartz-Shea, 2015). Triangulation is the independent application of multiple research methods in parallel. The empirical findings are triangulated to increase qualitative research credibility and validity (Cho and Trent, 2006). The triangulation entails both data triangulation with multiple data sources and method triangulation using various methods in the same research. Besides the above methods and data sources, promotional and documentary videos, a set of visits to the projects, and informal talks near the coffee machine and front desk were also used to triangulate the information provided by the direct data and informants, adding contextual information to and validating data of the analyses. For example, in the case of the GSP project, the research team members played different roles with access to different data sources. We together both complemented and compared the data and analysis. The researcher also used multiple theories and perspectives to interpret a single set of data. The triangulation of methods allowed a reliable and valid view of the research topic (Joslin and Müller, 2016).

Such integration could work in two ways: "outside-in" and "inside-out." It would be fascinating to study popular concepts in the literature and bring them into the project management debate about the "outside-in." Regarding the "inside-out," it would be essential to see how knowledge within the field of project management might enhance findings from the discipline. In this way, the validity and reliability of the data were achieved.

2.4 Data analysis

There was a significant overlap between data collection and data analysis, and they influenced each

other. As the study progressed, the data collection became more analytical as the research began testing ideas and concepts derived in the interpretation of the data already collected. The analysis first sought to investigate specific topics and understand issues within each of the three cases. Critical practices and phenomena were identified, relying on labels representing similar descriptions across multiple data sources. The researcher relied on qualitative coding for theory building by creating constructs and their relation by interpreting the data collected from three cases. Subsequent literature readings could help assemble these constructs into categories with similar definitions, issues, or relationships relevant to the informants. The data analysis would be executed back and forth between the cases and the concepts, tentative assertions, and raw data. The research proceeded to compare across the cases, to draw conclusions about cross-case patterns of project-based learning. In this way, the theory was built.

2.4.1 Content and thematic analysis

After documents, observations, and interview data were collected, a content analysis was completed to organize information into the main research question categories. This work was positioned as the first step in theory building. Once this categorization was completed, a thematic analysis involving pattern recognition was conducted. The main emphasis of thematic analysis is to identify common themes, such as patterns of meaning that come up repeatedly.

In the first step of data analysis, the researcher went through all the reports, interview data, and observational notes. The interviews were transcribed and translated from Dutch/Chinese to English. Each part of each transcript was thoroughly read and analyzed and categorized into codes. Codes were either directly found in the material or constructed from it (Larsson, 2010). In the second step, data were separated into units of meaning and then contextualized as they are later integrated and clustered into themes. Themes that came across in different data sources were, therefore, interlinked. A higher level of abstraction was conducted to analyze and synthesize emerging patterns or themes taken together. Such an analysis, in which data are understood within the context of the case, strengthens claims about actors' interpretations (Yanow, 2005). The insider and outsider researchers' perspectives were then drawn together to obtain a more in-depth, holistic, and enriched view (Yanow and Schwartz-Shea, 2015). In the third step, the literature was consulted to develop an analytical frame to refine these codes. Inspired by the literature, the sub-codes were merged and evolved into thematic values with the thematic analysis procedure. As a form of "member-checking" (Yanow, 2005), researchers discussed the thematic codes with several vital informants to verify findings.

2.4.2 Within and cross-case analysis

The advantages of the case study approach are the flexible approach to collecting data, the integral and holistic viewpoint to analyze data, and the high chance of reaching consensus with informants (Hertogh and Westerveld, 2010). However, low external validity may become one of the main disadvantages when

carrying out the case study (Gummesson, 2000). Using a multiple case study approach, the research sought to enhance external validity (Yin, 1983).

The research started with the within-case analysis to identify common constructs and their relationships within a single case. In Case MWW, the owner proactively advocates value co-creation with all potential market partners and knowledge partners. In Case GSP, the alliance name RIXWAS, an intertwining of IXAS and RWS, was created showcasing the relationship between the owner and contractor. In Case HZMB, the partnership is the philosophy pursued by the HZMB Authority. The owner requires the cooperation of all parties to solve problems around the target. These codes were classified as the condition of Leadership and later formulated the project-based learning principle – owner commitment. In this process, the study further clustered critical qualitative data under emergent themes to ensure the consistency between data and theory. The researchers repeated this process until all data were coded and classified, and the researcher was confident with the interpretations of the data.

The research performed an iterative coding and analysis in the cross-case analysis process to compare and contrast the patterns that emerged from individual cases (Eisenhardt, 1989; Haj-Yahia, 1998). The cross-case comparison is described as decontextualization and recontextualization (Tesch, 2013). Cross-case analysis can mobilize the knowledge from individual case studies and support the creation of clusters of phenomena. Using multiple cases to study a similar phenomenon allows us to detect the critical issues and consistent relationships between the variables. Engaging in cross-case analysis enables us to delineate and refine the combination and relationships of factors that contribute to answering the research questions.

The research accumulated case knowledge, compared cases and tried to produce new knowledge in Chapter 8. The building of theory was the final step, which involved a final interpretive process through multiple readings and iterations between tentative assertions and raw data and then drafting successive versions of the text until the present form is determined. The interpretations and discussions of the concepts enabled new understandings in each case and identified principles as the final recommendation.

2.5 Thesis layout and contents

This dissertation is structured into nine chapters. The core chapters (Chapter 5, 6, and 7) of this thesis have been published or submitted for publication as separate articles that can be read independently. **Table 2.1** shows the stages of this research and the corresponding methods.

Table 2.1 Research stages, questions, and main results

Stages of research	Sub research questions	Chapter research questions	Research methods	Main focus

Stage 1 conception	Literature review (Chapter 3)	Q1. What is the state of the art of the current learning in project studies and practice?	Q1.1 what is the state of the art of project-based learning?	Literature review	Theoretical foundation
	Empirical overview (Chapter 4)		Q1.2 what is the current status quo of project case bases in practice?	Desk research, content analysis	Problem definition
Stage 2 case study	MWW case study (Chapter 5 published in International Journal of Project Management)	Q2. How do large infrastructure projects carry out learning in good practices?	Q2.1 How does co-creation contributes to or limit the creation of value at the front end of programs?	Action research, case study; archival documents, interviews, participant observation; thematic analysis	Meta-project learning, the front end of program, co-creation
	GSP case study (Chapter 6 under review in Engineering, Construction and Architectural Management)		Q2.2 What are the effects of exploitative learning carried out by the inter-organizational project actors?	Ethnography, case study; archival documents, interview, participant observation; content analysis	Intra project learning, large on-going project, exploitative learning
	HZMB case study (Chapter 7 under review in Project Management Journal)		Q2.3 What critical strategies should be taken to promote explorative learning in megaprojects?	Case study; archival documents, interview, focus group discussion; thematic analysis	Inter project learning, completed megaproject, explorative learning.
Stage 3 synthesis	Synthesis (Chapter 8 and 9)	Q3. How can learning be promoted in large infrastructure projects?		Cross-case analysis	Principles to improve the project-based learning

The first stage mainly consists of a literature study and an empirical overview. Chapter 3 describes a systematic review of literature on project-based learning. The research reviews the literature systematically on learning from a project perspective. The study expects that most project-based learning research will be found and that learning is sufficiently representative for responding to the research questions. Chapter 4 presents a practical overview of project-based learning that explores the practice in infrastructure project case bases. The initial findings lead to the necessity of the following chapters.

In practice, the case study projects offer immense opportunity to research the learning process to manage infrastructure development programs and megaprojects. In the second stage, three qualitative case

studies are conducted. Each case is first analyzed as a single case study in order to identify why and how learning could be promoted in projects. The research uses various qualitative methods to study actors, daily practices, and social situations. Chapter 5 presents a case study of a Dutch navigation lock program, Multi Water Works (MWW) program, to investigate what stakeholders do in co-creation sessions and how this contributes to the co-creation of value at the front end of programs. Chapter 6 analyses the learning trajectory that occurred in the longest land-based tunnel project in the Netherlands, the Gaasperdammer tunnel project, and investigates the effects of exploitative learning carried out by the inter-organizational project actors. Chapter 7 draws upon case research into the Hong Kong-Zhuhai-Macao Bridge (HZMB) in China to study how the ability to explore was achieved and sustained in the megaproject. This stage aims to explore learning in different project phases (front-end and on-going execution) and different types of projects (programs and megaprojects) in real cases.

Finally, in the third stage, a synthesis study was performed. Chapter 8 is built from the earlier conducted studies described in chapters 5–7. Each case's evidence is considered to be information needing to be analyzed by the other individual case. This stage aims to integrate the earlier developed empirical findings into a set of propositions for practical use. Chapter 9 summarizes the overall research findings and presents an outlook on project-based learning in academia and practice.

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Chapter 3 Mind the Gap! Understanding the Unique Characteristics of Project-based Learning: a Literature Review

Abstract

Learning from past lessons in projects and presenting future project management activities is very important in large projects. However, a clear and in-depth understanding of project-based learning is relatively neglected. The research reviews the literature on learning from a project perspective based on the theoretical foundations of projects, project management, knowledge management, and organizational learning. The review analyzes and classifies the research on "learning" in the "project" published in the leading project management, construction management, knowledge management, and general management journals. The research focuses on the project as a temporary organization and within contexts. Emerging research shows fragmented definitions and suggests a distinction between project-based learning and organizational learning. Seeing projects as singular may inhibit learning in and from other projects. A theoretical analysis of project-based learning is provided by deepening insights on different dimensions, such as codification and personalization, exploration and exploitation. It is revealed that social interaction may be more effective than database learning in the current project environment and how to facilitate inter-project learning will require more research attention. This research scans state of the art and addresses the gap of project-based learning in the existing literature, which sets the direction of project-based learning research.

Keywords: Knowledge management, organizational learning, project management, project-based learning, literature review.

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3.1 Introduction

Over the past two decades, researchers have expressed interest both in learning theory and learning practice (Bresnen et al., 2003; Jarzabkowski, 2004; Scarbrough et al., 2004a; Tennant and Fernie, 2013). Bartsch, Ebers, and Maurer (2013) defined learning in project-based organizations as the process of integrating project knowledge, recognizing many learning opportunities through the projects they conducted with other partners. Ayas and Zaniuk (2001) argued that project-based learning is about using projects as means for setting the stage for reflective practices to reveal more profound insight and construct shared understanding. Love et al. (2000) envisioned that project-based learning is a continuous process of creating, acquiring, sharing, and transferring knowledge from both best practices and lessons learned. Practical experience gained from various projects enables project management to undergo continuous improvement across projects, including improving performance and competency and adapting to environmental changes (Yap et al., 2018).

The poor delivery performance of megaprojects has been criticized for decades. One of the reasons is that practitioners have not learned effectively from their project management experiences. Organizational boundaries and contractual concerns often hamper learning. Project knowledge that impacts project performance is often lost (Carrillo, 2005; Disterer, 2002; Maya et al., 2005; Newell, 2004; Newell et al., 2006; Williams, 2004). As prescribed in practice, project-based learning appears to be limitedly applied in project management (Scarbrough et al., 2004b).

The temporary and unique nature in the definition of projects is to blame for the difficulty in learning from projects for the benefit of the standing or mother organizations and follow-up projects (Prusak, 2009) in terms of avoiding a tendency to “reinvent the wheel” that leads to the increase in time and cost, and repeating the costly mistakes. A broad and in-depth understanding of learning is essential to enact the process. However, our understanding of project-based learning remains limited. There is no systematic review of learning in project studies to date, raising the question of the state of the art of project-based learning. The research aims to focus on the relatively unexplored area of learning in the project-based context. The review addresses the gap by asking what learning means in the project setting and the characteristics of project-based learning. The research started with a review of various perspectives on and definitions of a project, project management, knowledge management, and organizational learning to answer this question. A systematic literature review was then undertaken to summarize the characteristics of project-based learning research, including theoretical angles and levels and potential future trends. The review reveals insights that the literature offers into the dynamic nature of project-based learning.

3.2 Theoretical foundations

3.2.1 Project as a form of the temporary organization

At the earliest, Lundin and Söderholm (1995) introduced the temporary organization defined by tasks, time, team, and transition. Lundin and Steinthórsson (2003) emphasized the scarcity of the contextualization approach for studying organizations as temporary phenomena. Lundin and Söderholm (2013) rethought the concept of temporary organization. They proposed the new notion that "end states" constitute the project processes' essence, taking the Sydney Opera House project as a perfect example. The most cited article on the project's temporary challenge is published by Engwall (2003). He compared two cases and found an anomalous phenomenon: in one project, there existed excellent project management systems and very experienced project managers, but in the end, the project was a failure, while in another project, though confronted with a lack of project management system and project managers who did not receive systematic project management training, in the end, it was very successful. Engwall called for an extended perspective to link the project time dimension and organizational context. The pinnacle of current understanding is provided by Bakker (2010). He further recognized the temporary organization in project management research with an integrative framework around four central themes: time, team, task, and context. He was the first to systematically describe the development of temporary organizations and publish in mainstream management journals. Winch (2014) further developed the definition of project organization as a specific union formed by permanent organizations to deliver a particular outcome. Long-standing firms undertake repeatable and predictable patterns of activities (Cyert and March, 1963; Davies and Brady, 2000). The temporary project-supported or project-based system is embedded in the respective formal permanent organizations and networks (Hobday, 2000). This debate on the nature of projects is yet to be resolved.

Projects as a form of temporary organization are commonly created in order to fulfill a unique purpose (product, service, or result) (Lundin and Söderholm, 1995; Turner and Müller, 2003). PMI (Project Management Institute) defines the project more precisely as a temporary endeavor undertaken to create a unique product or service (Project Management Institute, 2017). Project-based organizations are commonly seen as the common mode of organizations in a variety of industries. The delivery of the infrastructure projects is characterized by firms organizing themselves around projects. The nature of this type of organization has relations with many barriers, such as one-off, temporary, complex and linear form of tasks with non-routine behavior, several organizational units involved in a decentralized project team (Brady and Davies, 2004; Bresnen et al., 2004; Burke and Morley, 2016; Hobday, 2000; Lundin and Söderholm, 1995; Packendorff, 1995), among which, the temporary and unique nature stands out most significantly.

Researchers have concluded that the temporary and unique nature causes problems to replicate their solutions to deliver products and achieve economies of scale in the management of most projects

(Shenhar and Dvir, 1996; Söderlund and Tell, 2009). For many project managers, some megaprojects are often once-in-a-lifetime. The uniqueness of projects also lies in differences in teams for each project. The temporary and unique nature of projects challenges how knowledge flows within and between projects (Almeida and Soares, 2014; Lindner and Wald, 2011).

3.2.2 Project management as middle-range theory

Project management is a discipline different from general management. In the prior literature, two of the most significant topical issues to make project management special are temporary organizations and their context.

Conventional project management emerged in the second half of the 20th century in the defense and aerospace sectors. Since then, project management has emerged as a distinct field of discipline with its own tools, techniques, and knowledge body. Then the theory of project management evolved with the development of the construction and IT industry. Early project management research and practice are more concerned with the technical side, emphasizing the Gantt chart, critical path method, etc. The relationship between context and practice was mostly ignored (Engwall, 2003; Kreiner, 1995). Standard practices in project management often overlooked the inherent uncertainties linked to infrastructure projects' length and scale and their continually changing and complex environments.

Professional bodies heavily influenced the initial establishment and the ongoing development of project management. With the evolution of project management in the development of the construction and IT industry, different project management standards are used in the project such as PMI's PMBOK (Project Management Body of Knowledge), IPMA (International Project Management Association)'s Project Excellence Baseline, UK Government's PRINCE2 (PRojects IN Controlled Environments), ISO 21500:2012 guidance for project management, etc. Among them, PMI and its Project Management Body of Knowledge (PMBOK) are widely accepted (Abdul Rasid et al., 2014; Thomas and Mengel, 2008).

Although the utilization of project management tools, techniques, and standards has improved significantly in recent years, many projects still fail. Several researchers have criticized PMBOK. Some argued that PMBOK is overly biased toward solid project management skills/knowledge, rather than the soft project management skills (e.g., communication and reflective skills) (Crawford and Pollack, 2007, 2004; Pant and Baroudi, 2008). Other researchers further pointed out the narrow focus in the PMBOK Guide (Söderlund, 2011) that project management started to develop as a professional and specialized managerial discipline rather than as an academic discipline. Professional bodies codified project management principles and procedures by inducing from the practice, not from theoretical starting points (Morris et al., 2006). The PMBOK Guide is not based on robust and consistent theories but more on empirical evidence that lacks a strong theoretical base. Turner believed that one approach is better than another to managing a project is still primarily based on faith more than sound knowledge (1999).

Söderlund and Maylor criticized project management as too applied and too close to practice for proper academic study (2012). Project management research conclusions are more practical, not to provide theoretical relevance (Pitsis et al., 2014).

Therefore, project management mostly belongs to the middle range theory, a theory with limited scope. It emphasizes practical experience and requires evidence from the real world. As a result of the practical experience, project management is no longer a valid macro range theory but can be derived from a series of assumptions to explain the case. The theory can be verified or overturned by a single project. These features align with Merton's understanding of the middle range theory (Grey et al., 2005).

3.2.3 Knowledge management

The field of knowledge management has steadily grown over the last three decades since its emergence in the 1990s, with contributions from different academic ambits, such as knowledge epistemology, organizational learning, ICT approaches, and knowledge-based views of the firm. There are several perspectives on knowledge management (Bhatt, 2001; Grover and Davenport, 2001), but all share the same core components: People, Processes, and Technology. Some take an IT-centric focus in order to enhance knowledge integration and creation (Kankanhalli et al., 2005, 2003); some take an organizational focus in order to optimize organization design and workflows (Jung et al., 2007; Zack et al., 2009); some take a human resource focus, where the critical aspects are related to people interaction, knowledge and environmental factors as a complex adaptive system similar to a natural ecosystem (Cabrera and Cabrera, 2005; Chow and Chan, 2008).

The traditional view classifies knowledge into separable explicit knowledge and tacit knowledge (Nonaka, 1994; Polanyi, 1959). Explicit knowledge is relatively simple to codify and disseminate, while tacit knowledge is hidden in individuals' cognition. Knowledge management is the discipline of creating a thriving work and learning environment that fosters the continuous process of creating, capturing, sharing, transferring, and using knowledge to pursue new business value (Cross, 1997). It is concerned with the analysis and technical support of practices used in an organization to enable the adoption and to leverage good practices embedded in collaborative settings and, in particular, in organizational processes. Effective knowledge management is an increasingly important source of competitive advantage (Carneiro, 2000) and a key to contemporary organizations' success, bolstering the collective expertise of their employees and partners.

Almost all mature corporations put knowledge management as an essential item on their agenda. Knowledge management has been an old question in project studies. The management of project knowledge is now recognized as a vital ingredient for competitive business performance in the AEC (architecture, engineering, and construction) industry. Numerous scholars have studied the issue of how to carry out knowledge management actions in the project environment (Havermans et al., 2014;

Isabalija et al., 2011; Love, 2003) and construction firms (Carrillo and Chinowsky, 2006; Forcada et al., 2013). However, many project participants make poor use of such a rich resource. Project management's main problems are mainly associated with the industry's characteristics because a typical construction project is temporary, unique, and involves various project parties working on different divided tasks. Project management organizations will have to address the boundary paradox that, on the one hand, it is vital to be proactive to absorb knowledge beyond their organizational boundary from both partners and markets on both a formal and informal basis. On the other hand, they must protect their knowledge from imitation by others (Quintas et al., 1997). Due to the adversarial relationships and price competition, the industry suffers from fragmented information flows and remarkable distrust between clients and contractors (Fearne and Fowler, 2006). It can be concluded that there are insufficient knowledge sharing and transfer within and between organizations.

A primary stream of research has focused on developing methodologies to capture and reuse the knowledge created and lessons learned in projects (Buttler, 2016; Kivrak et al., 2008; Li et al., 2013). A list of related research projects demonstrates the growing interest in knowledge capture, sharing, and transfer in construction projects (for more information, see **Appendix 3.A Table 3.1**). There have been quite a number of large research projects in the UK that sought to examine the problems of knowledge management. The experiments in the 1990s to develop a knowledge management model, framework, or database have largely proven to be futile.

3.2.4 Organizational learning

However, learning is a broader concept consisting of different subsets based on the context and organizational type. Concerning its magnitude and impact, it can range from minor, incremental improvements (Hippel, 2005) to the pursuit of fundamentally different approaches leading to radical breakthroughs (Bayus, 2013).

Cyert and March (1963) coined the term organizational learning to describe the adaptive changes of organizational routines and rules based on their experiences. Following Senge's (1991) publication of The Fifth Discipline: The Art and Practice of the Learning Organization, organizational learning has become a bestseller topic in the management world. In effect, the nature of the attention paid to organizational learning emerges from a shift in traditional industries' management practices, such as car manufacturers, oil, and gas, which replicate their solutions to deliver products and achieve economies of scale (Söderlund and Tell, 2009).

Organizational learning literature rests on fundamental assumptions that learning is 1) experiential, 2) behavioral, 3) social, and 4) organized, which is a complex process that deals with knowledge development and behavior change (Huber, 1991; Slater and Narver, 1995). Therefore, organizational learning is defined as the social production of organizational rules based on collective experience that

leads to a changed organizational behavior (Holmqvist, 2003).

Literature suggested three general steps of learning: single, double, and triple-loop learning (Snell and Chak, 1998). Single-loop learning typically focuses on behavioral changes, improving existing actions and techniques within an existing framework to increase efficiency and effectiveness, and reach the set objectives. However, it does not address underlying routines and assumptions. Errors are restored in a system without looking at the underlying cause. Double-loop learning is applied in cases where routine solutions no longer work. This requires reflection, dialogue, and transformative changes after undertaking a comprehensive review of root causes of errors and underlying assumptions (Argyris and Schon, 1974), which provides the opportunity for more meaningful or fundamental learning. Triple loop learning goes one step further. At this level, it is not so much about finding a solution to a problem but about optimizing the learning capability: learning from learning.

Organizational learning and project management are directly related and occur together (Ahern et al., 2015; Kaj U. Koskinen, 2012; Kotnour, 2000; Wong et al., 2009). However, the formal organization's focus view still dominates the current literature, with less attention to projects. When learning does occur in projects, it is generally single-looped (SL) (Wong et al., 2009). The learning process is still plagued with challenges. The temporary nature of project organizations and the structural complexity of projects inhibit such learning (Lindkvist et al., 1998; Prencipe and Tell, 2001; Williams, 2008).

3.3 Methods

Born in the medical sciences, a systematic review is a transparent and rigorous method to consolidate and synthesize information from diverse sources on a clearly defined problem (Grant and Booth, 2009; Tranfield et al., 2003). This research adopted the systematic literature review and was conducted in four steps. The articles were accessed from August 17th, 2018, to June 10th, 2019.

First, journal selection. Specific peer-reviewed academic journals were selected to prevent a lack of inferior quality of the articles included in this review. Therefore the review is based on a reasonable rather than comprehensive coverage without jeopardizing its conclusion (Miterev et al., 2017; Rowe, 2014). Journals were selected from project management, construction management, knowledge management, and general management. In the project management field, the chosen journals include three leading journals recognized by Project Organising Track EURAM (The European Academy of Management), International Journal of Project Management, Project Management Journal, and International Journal of Managing Projects in Business. Highly influential project-related construction management research journals[1] include Journal of Management in Engineering, Journal of Construction Engineering and Management, Journal of Civil Engineering and Management, Engineering

[1] The literature review deliberately covered the construction management journals because the thesis topic is around learning in large infrastructure development projects.

Construction and Architectural Management and Construction Management and Economics. These journals are widely recognized for publishing project-specific academic research, especially in the construction domain. Besides, the leading knowledge management journals and general management journals (UT Dallas journal list and Financial Times Top 50 Journals Used in Business School Research) were also included (see **Appendix 3.B Table 3.5**). All these journals have been considered relevant to "learning" or/and "project."

Second, article selection. The central academic database Scopus was consulted for article search and selection. The keywords "learning" AND "project" in the title, keywords, and abstract within the selected journals were used to search for articles. 337 articles were found, with 143 from project management journals, 132 from construction management journals, 23 from knowledge management journals, and 39 from general management journals. Even though our sample is not exhaustive due to the selected journals, it is expected that most project-based learning research would have been found, and they are sufficiently representative for responding to our research questions.

Third, article screening. The search results were scrutinized to ensure that the articles listed were relevant by reading all article abstracts. The range of articles was narrowed down for analysis to fit the purpose of this study. Those articles focusing on teaching and education (27 articles) and machine learning related research (21 articles) were removed. These articles mainly appeared in construction management and project management journals.

Fourth, content analysis. The primary authors' articles were chosen as the seminal foundational work and identified relevant analytical categories. It is attempted to summarize the characteristics of project-based learning research, including definitions, theoretical angles and levels, and potential future trends.

3.4 Overview of results

3.4.1 Distribution of articles

The majority of journals covering "project" and "learning" come from project management journals, with the most articles published in International Journal of Project Management (see **Appendix 3.B Table 3.2**). The remaining articles are evenly distributed in knowledge management journals and construction management journals (see **Appendix 3.B Table 3.3** and **Table 3.4**). Besides, few identified articles can be found in general management journals, except for some published in Research Policy, Management Science, Expert Systems with Applications, and Organization Studies (see **Appendix 3.B Table 3.5**).

When filtering articles with "project," no articles are found in many general management journals such as Academy of Management Review, Academy of Management Journal, and Journal of Management. Only a few pieces of literatures appear in journals such as Management Science, Organization Studies,

and Research Policy. Temporary organizations have remained part of the business management "family," albeit a quiet, unobtrusive member (Bakker, 2010). When discussing the theme of learning, the formal organization's focus view still dominates the current literature, with less attention on the project level.

3.4.2 Publications in years

Figure 3.1 presents the trend in project-based learning articles over time. The analysis interval is 1994-2018, as only part of the data in 2019 was obtained. During 1994-2018, there is an average number of 11.36 articles, and the largest publication number with 29 appeared in 2008. The number of articles has experienced a significant increase since 2001. However, it is not a consistent growth. It remains stable in recent years.

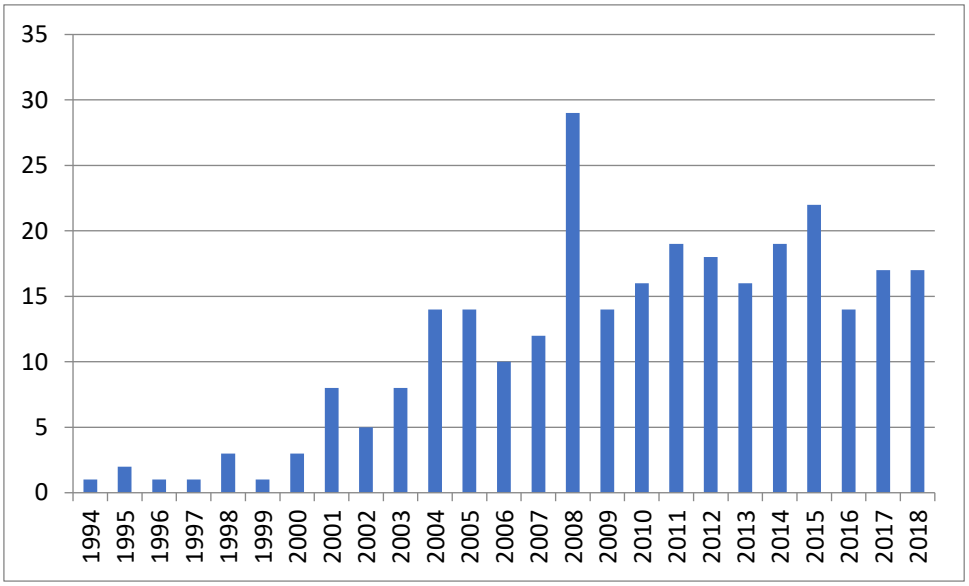

Figure 3.1 Publication trend in years

3.4.3 Main authors

According to the list of primary authors working on the topic of project-based learning (see **Appendix 3.C Table 3.6**), only a few authors pay attention to the topic of project-based learning in a continuous way. Andrew J. Sense is the most productive researcher, with almost all articles written solitary.

Interestingly, several co-authors regularly collaborated on the topic. They are 1) Mike Bresnen, Jacky Swan, Linda Edelman, Sue Newell, and Harry Scarbrough; 2) Terence Ahern, P.J. Byrne, and Brian Leavy; 3) Peter S.P. Wong and Sai On Cheung; 4) Peter E. D. Love and David J. Edwards; 5) Hamzah Abdul-Rahman and Jeffrey Boon Hui Yap; 6) S. Jonathan Whitty and Stephen Duffield. These scholars published their work mainly in project management journals. The group of Mike Bresnen, Jacky Swan,

Linda Edelman, Sue Newell, and Harry Scarbrough successfully made it to the flagship management journal (Organization Studies).

3.5 Defining project-based learning

3.5.1 Weakly undefined term

Learning looks like a buzzword. The terminology has not been explicitly defined in the literature. There is no agreed and precise term to describe the topic, and there are many ambiguous terminologies relevant in terms of project-based learning from literature. There are many categories of "learning" in the existing literature: multi-project learning (Midler and Silberzahn, 2008), cross-project learning (Alashwal and Abdul-Rahman, 2014; Newell et al., 2006), inter-project learning (Alashwal and Abdul-Rahman, 2014; Prencipe and Tell, 2001), learning from projects (Williams, 2003), project-based learning (Bakker et al., 2011; Bresnen et al., 2003), cross-program learning (Dutton et al., 2014), learning in between projects (Hartmann and Dorée, 2015), learning from and within projects (Scarbrough et al., 2004b), and model development for intra-organizational project learning (Brady and Davies, 2004), etc., among which, project-based learning is most commonly used.

Under the umbrella of learning theory, project-based learning is interpreted in different ways. Different theoretical schools are now embedded within the overall concept of learning, including social learning (Hartmann and Dorée, 2015), action learning (Schindler and Eppler, 2003), reflective learning (Perminova et al., 2008), practice-based learning (Bresnen et al., 2005), method-based learning (Bijleveld and Dorée, 2014), experiential learning (Savelsbergh et al., 2016), cultural learning (Chandra and Loosemore, 2010), cooperative learning (Janz and Prasarnphanich, 2009), and entrepreneurial learning (Ravasi and Turati, 2005). They all work towards the same definition but use different terminology. This shows a much broader scope of the concept but lacks a sound theoretical foundation in this topic.

As a result of the messiness in the field, project-based learning can mean different things to different researchers. Scarbrough et al. (2004) defined project-based learning by conceptualizing both the creation and acquisition of knowledge within projects and the consequential transfer of this knowledge to the broader organization and other projects. Bartsch et al. (2013) defined learning in project-based organizations as the process of integrating project knowledge, recognizing many learning opportunities through the projects they conduct with other partners.

Besides, learning is frequently mentioned in the literature on topics such as innovation. Innovation is very often modeled as a function of experience. The point is that the past offers little guarantees for the future. As increasingly exploratory projects focus on knowledge creation and learning (Lenfle, 2008), incremental innovation's cumulative power appears in project studies (Berggren, 2019). Projects can be

improved through learning to implement innovations by the “recombination” and “replication” of elements in the project system (Davies et al., 2009).

3.5.2 Learning in organizations and projects

Much research has been done into learning in organizations, mostly at the firm level. Plenty of theories deal with types of knowledge in organizations, how knowledge in organizations can develop and how it can be recorded and shared, how conventional organizations learn from unusual experiences and learn to respond (Garud et al., 2010; Weick, 1991).

Project-based learning is a subset of the organizational learning theory (Keegan and Turner, 2001). Some research makes a clear distinction between organizational learning and project-based learning (Chan et al., 2005; Kaj U Koskinen, 2012; Scarbrough et al., 2004b). The call for linking organizational learning with project-based learning has been seen several times in our literature review.

Despite the diversity of perspectives, there is no significant difference in learning mechanisms in the project and other types of organizations. Prencipe and Tell (2001) provided a clear framework distinguishing three learning processes: experience accumulation, knowledge articulation, and knowledge codification both at the project and organizational levels. Brady & Davies (2004) combined learning at the project and organizational levels. In the early exploratory projects, there is mainly learning within and between the projects. In later projects, the interaction between projects and organizations is playing a role. There are differences in the focus of the process. In the early phase, exploration of new activities is the focus, and later the focus turns to knowledge sharing and transfer between organizations. This is the path for the current design and construction firms to carry out project-driven learning and business-driven learning. Swan et al. (2010) also analyzed the influence of different organizational structures on experience accumulation and learning. Influential functional organizations generally rely on individuals and groups to accumulate experience and learn from projects due to undertaking multi-projects learning. The project centered organizations have a better accumulation of experience (Bayer and Gann, 2007) though also relying on individual and team experience.

The term project-based learning is used inclusively to encompass knowledge sharing within projects (Ayas and Zeniuk, 2001) and knowledge transfer to other projects and wider organizations (Bakker et al., 2011; DeFillippi and Arthur, 1998; Scarbrough et al., 2004b). Organizational learning in project-based organizations refers explicitly to the process of making newly created project-level knowledge available to the organization as a whole by sharing, transferring, and reusing it (Bartsch et al., 2013; Prencipe and Tell, 2001).

Brady and Davies (2004) have an interesting point of view on project-based learning. They believed that project-based learning could be analyzed and understood to build project capability over time. In this

sense, project capability refers to the specific knowledge and experience required to engage with customers, set up, and implement projects.

3.6 Current role of project-based learning

3.6.1 Project learning paradox

The concept of the learning paradox of projects was introduced by Bakker et al. (2011) when observing the transferability of knowledge between projects. They emphasized the fact that on the one hand, compared with operation centered corporation management, projects are temporary and fluid (Gann and Salter, 2000; Grabher, 2004a; Hobday, 2000), thus making them suitable for stimulating and generating knowledge. However, on the other hand, projects are discontinuous and often relatively short-lived, restricting the assimilation of this generated knowledge to other projects. In this case, knowledge lies with people themselves and will be assimilated through them to other projects. Corporations may be slow in creating new knowledge, but it is easier for them to sediment and transfer knowledge. The learning paradox concept refers to this dilemma between the ease of knowledge creation and the difficulty of knowledge dissemination.

Projects are viewed as a temporary endeavor to deliver unique work (Project Management Institute, 2017). According to Ayas & Zeniuk (2001), a significant amount of learning may occur within a project. On the one hand, projects are very suitable for creating new and fast knowledge in the transient and inter-disciplinary context (Braun et al., 2012; Gann and Salter, 2000; Grabher, 2004b; Hobday, 2000; Scarbrough et al., 2004b). On the other hand, the temporary and unique nature of projects also restricts storing knowledge, because as soon as the project team is dissolved and participants move on, the created knowledge is likely to be gone (Braun et al., 2012; Cacciatori, 2008; DeFillippi and Arthur, 1998; Grabher, 2004b; Ibert, 2004). If specific knowledge and experience are not directly managed in the project, organizational amnesia begins (Schindler and Eppler, 2003). Learning is now seen as something extra but is not an integral part of the whole project. Therefore, more interests are attracted to projects' presupposed inabilities to sediment project knowledge because of their uniqueness and temporality (Bakker et al., 2011; Prencipe and Tell, 2001).

3.6.2 Knowledge management and learning

The concept of learning is directly related to knowledge management (Zollo and Winter, 2002). There are parallels between the literature on knowledge management and project-based learning. In our literature review, studies use the concept of learning in the project setting to describe the process of creating, sharing, transferring, and reusing project knowledge (Prencipe and Tell, 2001; Scarbrough et al., 2004b). Knowledge management can be seen as a managed learning.

In the project environment, knowledge enables project teams to make decisions, apply them to actions,

and solve problems. The integration of knowledge from successful and unsuccessful projects into the current project management processes has become necessary for staying profitable and competitive. These areas are generally referred to as encompassing two traditional knowledge management processes: capturing essential knowledge within project ventures and making effective use of it for a broader environment (Davenport and Völpel, 2001). However, the literature on project-based learning typically focuses on establishing approaches for creating and storing project knowledge and less on reflecting and reusing project knowledge in subsequent tasks and future projects. The majority of research has been carried out on knowledge capture (Tan et al., 2006; Udeaja et al., 2008). Therefore, although project knowledge has been created and stored, it is barely perceived and reviewed (M. von Zedtwitz and von Zedtwitz, 2003; Newell, 2004). When moving from project to project, the challenges of using project knowledge have yet to be adequately addressed systematically (Cooper et al., 2002; Newell, 2004). There is a call for a more systematic distribution of learning within and from projects. More empirical support is encouraged for the emerging theories of project-based learning.

3.7 Levels of project-based learning

3.7.1 Intra- and inter-project learning

Knowledge is moving within organizations, but also across boundaries between organizations. Project-based learning may occur in two main directions: Intra-project learning and inter-project learning (Swan et al., 2010).

Intra-project learning is creating and sharing knowledge and experience on tasks within the single (same) project (Gieskes and Ten Broeke, 2000). It contributes to delivering a successful project by selecting solutions and solving problems during the process (Kotnour, 2000). It occurs during learning from the tasks at hand, interacting with other actors on a project, and reusing the existing knowledge in the organization, which may lead to creating and sharing new knowledge (Chronéer and Backlund, 2015). This perspective may encourage practitioners to understand the necessity for project-based learning to make sense of their activities and develop their competencies (Love et al., 2014).

On the other hand, inter-project learning refers to the transfer of knowledge and experience (e.g., efficient ways of undertaking existing activities) from one project to other projects and into the broader organization (Prencipe and Tell, 2001). It involves the sharing and transferring of best practices and lessons learned by information technology tools and community of practices across projects to apply and develop new knowledge (Kotnour, 2000). It is still challenging to implement inter-project knowledge transfer (Swan et al., 2010). When it comes to learning between projects, we see much of Plan, Do, Reinvent history, File, and forget instead of Deming's Plan, Do Check, Act. There is an increasing call for leveraging learning and reusing knowledge across projects (Duffield and Whitty, 2014; McClory et al., 2017). Duffield and Whitty (2014) proposed an adaptation of the Swiss Cheese Model

to help organizations conceptualize how to learn from project experiences and disseminate them throughout the organization.

Figure 3.2 describes the two main categories of project-based learning. A-E in the ellipse and the circle represent project-based organizations and their sub-organization in the projects (expressed as the rectangles). The dotted lines between circles within the rectangles refer to intra-project learning, while the solid lines linking the ellipse C and circles (C1 and C2) refer to inter-project learning and learning from projects to the broader organization (A, B, D, E). Inter- and intra-project learning cannot be separated. Failure to learn within a project will restrict sharing useful insights for future projects or the organization at large, thus reducing the value of inter-project learning. Conversely, adequate intra-project learning requires access to insights, knowledge, and experiences gained from previous projects in order to create a fertile learning environment for individuals and teams in the focal project.

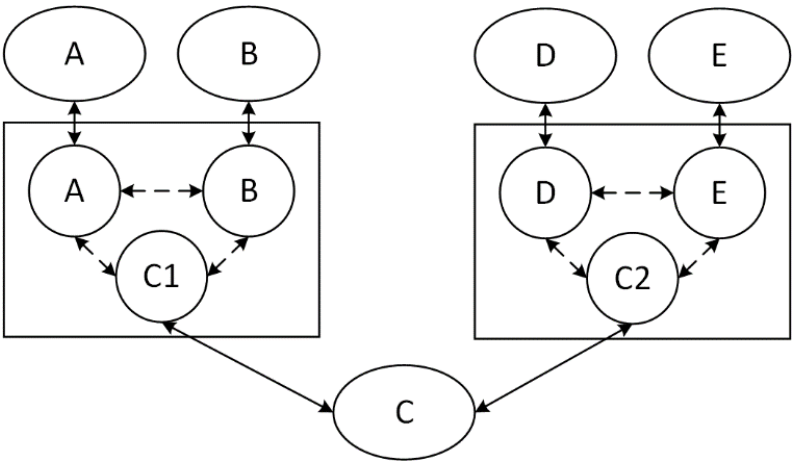

Figure 3.2 Intra- project learning and inter-project learning

3.7.2 Codification and personalization

The knowledge in projects can be embodied in the people in the organization and in the data stored in the organization's information systems, i.e., codification and personalization (Hansen, 1999). It can be transferred on the one hand via face-to-face interactions and, on the other hand, via documentation and database. The former requires productive social interaction and participants' engagement in practice and defines learning as emerging from informal and open interactions within social processes in networked environments (Ellison et al., 2015; Van den Hooff and Huysman, 2009). While the latter requires a formal data analytics approach to turn data into useful knowledge that is input for significant business decisions, fostered by information technology and computing power growth (Huysman and De Wit, 2004; Van den Hooff and Huysman, 2009). This apparently comes from the distinction between explicit and tacit knowledge (Nonaka and Takeuchi, 1995) and the technology side and human side of knowledge management (Alvesson and Kärreman, 2001; Gloet and Berrell, 2003). The configuration or the set-up

of the two different strategies within one organization has long been discussed among researchers in our literature review. The two strategies are dealt with as different yet complementary dimensions of knowledge management.

Earlier studies focused on tools and systems design of capturing knowledge for reuse in the future (Tan et al., 2006; Udeaja et al., 2008). They have mainly been associated with developing and applying expert systems (Alkass and Harris, 1988; Hanna et al., 1992; Russell and Al-Hammad, 1993). However, it encountered slow scientific progress due to the limited information technology capabilities and the main focus on managing easily handled knowledge by neglecting potentially more useful tacit knowledge (Easterby-Smith and Prieto, 2008) after the boom at the beginning of this century. The use of these expert systems only emphasized supporting intra-organization groups rather than a broader project network. There was a need to outline specific problems, describe best practices and lessons learned, etc.

Garrick and Clegg (2001) stressed the role of reflection and personal experience in project-based learning. Although it has been acknowledged that every project is unique, there are always some reusable processes (Carrillo, 2005). Hartmann & Doree (2015) argued that it is simplistic to have a more traditional sender/receiver perspective on learning. The sender/receiver perspective assumes knowledge as a transferable commodity and learning to transmit knowledge between the sender and the receiver in projects. They suggested observing progress and social interactions as a tool in understanding and enhancing project learning activities. The broader organizational vision is recognized to emphasize acquiring and processing of information and knowledge through social processes.

3.7.3 Exploration and exploitation

In the organizational learning literature, exploration (creating new knowledge) and exploitation (using existing knowledge) are typically distinguished (Crossan et al., 1999), which is presented as the lens of ambidexterity (Gibson and Birkinshaw, 2004). Exploitation and exploration can bring the benefits of increased efficiency and innovation separately (Easterby-Smith and Prieto, 2008). Ambidexterity is claimed to be beneficial at the organizational level, but little is known about how it is achieved in projects. Now it is more often discussed in the project context (Eriksson and Leiringer, 2015) since it requires exploitation (controlled processes) together with exploration (problem-solving) (Huemann, 2013).

Research on ambidexterity in projects has pointed out that ambidexterity might occur in single projects, which underscores the significance that project management not only centers on exploiting old knowledge but also can foster more innovative and exploratory activities (Turner et al., 2013). Eriksson et al. (2017) identified three critical exploitative learning themes: processes as incremental development, knowledge sharing, and innovation diffusion. Projects benefit from exploitative inter-project learning to efficiently use limited project resources (Eriksson and Leiringer, 2015). Davies et al. (2016) link uncertainty to the exploration side. Exploration was found to be a useful strategy in studies (Browning

and Ramasesh, 2015; Ramasesh and Browning, 2014) on reducing unknown unknowns in projects. As exploration and exploitation need different organizational structures, processes, strategies, capabilities, and cultures, more research is needed to study how exploration and exploitation are traded-off and managed at the project level (Turner et al., 2015).

3.8 The nature of project-based learning

In the organizational learning perspective, the organization is seen as a medium to store and reuse knowledge. This perspective has limitations in the project setting. The temporary organization is not adequately supported to accumulate knowledge in the multi-discipline practices. This is particularly critical where knowledge is "sticky" (Szulanski, 2000) and tacit in the context of non-repetitive project work (Duryan and Smyth, 2019). The project-based learning perspective emphasizes hybrid methodologies to integrate internal and external competencies; however, the environment is rapidly changing, making it more challenging to set a particular strategic direction.

Summarizing literature around "project" and "learning," project-based learning covers both the theory and practice on the use of project setting for effective action learning on real problems to achieve tasks and performance objectives (DeFillippi, 2001; Smith and Dodds, 2017). Project-based learning, which is mainly "ad hoc," requires commitment and continuous investment of time and resources, yet it is often neglected (Davies and Brady, 2000; Williams, 2008). Another perspective with implications for project-based learning argues that learning occurs naturally through social participation in the community of practice tradition (Brown and Duguid, 1991; DeFillippi, 2001).

Project-based learning practice can be defined as a set of actions that the project participants use to share knowledge within the project (intra-project), transfer knowledge across projects (inter-project), and ultimately reuse the knowledge (Kotnour and Kurstedt, 2000). Zollo and Winter (2002) developed three learning mechanisms: the experience accumulation (learning by doing), knowledge articulation (learning by discussing), and knowledge codification (learning by formalizing) while Prencipe and Tell (2001) tailored the mechanism in the project setting as explorer, navigator, and exploiter.

Projects combine multiple participants in collaborative teams and inter-organizational structures to create new knowledge (Edmondson, 2012). Project-based learning has been very challenging to achieve due to projects' temporary and unique nature. It is less likely to simply copy and paste the organizational learning theory developed from other routine-based industries to the project context (Bresnen and Marshall, 2001). The evolution of project-based learning theories in the infrastructure projects may be thought of as a progression from the broad organizational learning theory to more specific theories in project studies.

3.9 Discussion and conclusions

The research has reviewed the literature on learning from a project perspective. Project-based learning has been studied from diverse perspectives. The review demonstrated some of the major themes in the extensive literature, such as knowledge management, organizational learning, codification and personalization, exploration, and exploitation. Learning is the central mechanism to link all the above concepts together. Synthesizing insights from the general trend and several vital studies are framed in **Figure 3.3**. The framework can provide a bird's eye view of the state of the art of theoretical development on project-based learning and sets the direction for later chapters as follows:

1, Although there has been a large body of studies published on organizational learning and knowledge management, we call for more contributions in examining learning in and through projects (Intra- project learning and inter-project learning), especially in the development of large infrastructure.

2, The learning paradox is generally agreed that there is a dilemma between the ease of knowledge creation and the difficulty of knowledge dissemination in the project setting. We need to figure out mechanisms to guide future actions to better facilitate project-based learning processes. The social side of learning has long been acknowledged but perhaps less emphasized in project studies.

3, There have been many construction project management studies and experiments to develop a knowledge management model, framework, or database that have largely proven to be futile. It is suggested to observe social interactions and processes to understand and enhance project learning activities.

4, Two hands of learning, exploration and exploitation, need different organizational structures, processes, strategies, capabilities, and cultures. More research is needed to study how exploration and exploitation are managed at the project level separately.

The next chapter on the project case bases discusses the limited value of codification and calls for more social learning. Chapter 5-7 will carry out three case studies on intra-project learning and inter-project learning, explorative learning, and exploitative learning separately in project-based settings. The main argument is that project-based learning is essential and that more work should be done on it, which begs the question of "so what."

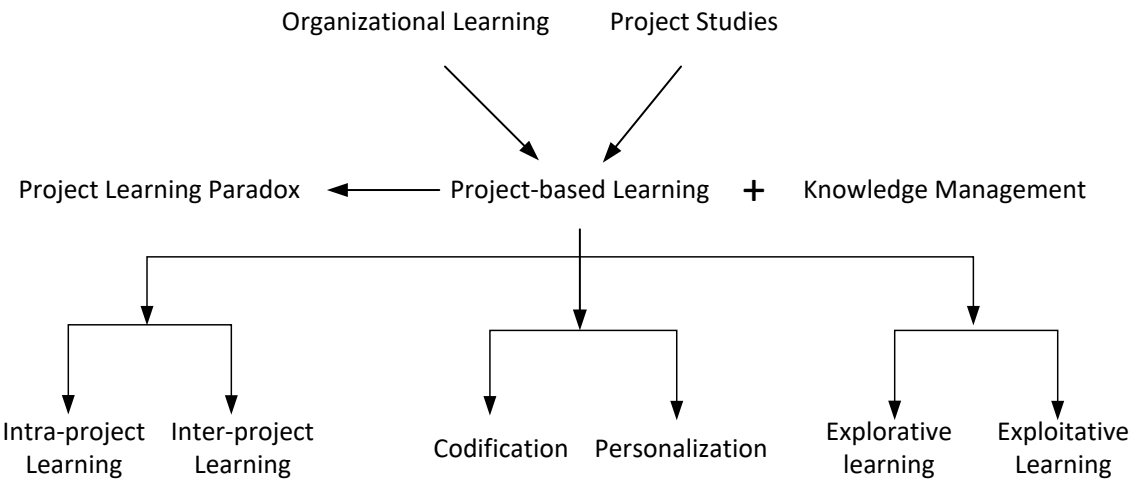

Figure 3.3 Project-based learning literature finding structure

Global Project Opportunities and the Complexity and Uncertainty are features of projects and their environment (Sakhrani et al., 2017). The frameworks and models of learning developed for formal organizations (Duffield and Whitty, 2014) may not apply to projects as temporary organizations (projects). Further research is needed to address this gap in extant literature (Sergeeva and Roehrich, 2018). The traditional view of learning is becoming problematic with the increase in globalization, changes in technologies, and an increased reliance on projects.

One most important finding is that much of the literature on learning in the project domain is still in a fragmented state, lacking a universally accepted research concept and a clear boundary. The development of project-based learning theory is adopted from and vigorously mixed with organizational learning, but the link between them may be far from seamless (Swan et al., 2010). Research on project management is under-represented in the leading general management and organization journals (Bredillet, 2008; Kloppenborg and Opfer, 2002). The project learning paradox is commonly agreed upon by project scholars. There is a significant overlapping between knowledge management and learning. Learning is a metaphorical term characterized by the mental representation of improvement. The concept of project-based learning still requires more definitional clarity to move forward.

It implies different project-based learning mechanisms. This research provided two dimensions: exploration and exploitation, codification and personalization. The existing research is more focused on the knowledge transfer within the project team. Inter-organizational knowledge management is still less explored. As construction projects rely much on inter-organizational relations, more consideration needs to be given to the multi-party cross-project knowledge transfer process, which is the unavoidable part of project-based learning.

The literature on project-based learning suffers from two significant shortcomings. Firstly, it is unclear

under which conditions the learning processes become effective. Applying the knowledge acquired during one project in a subsequent project is not easy and will not automatically be achieved. The effectiveness of codification and personalization processes is argued to be influenced by factors such as environmental conditions, organizational characteristics, and task features. However, empirical research on these conditions is scarce. Secondly, the learning mechanisms often are discussed in an intra-organizational instead of an inter-organizational context. Learning across inter-organizational projects can be assumed more challenging because of the involvement of multiple organizations with incongruent goals, overlapping areas of responsibility, and unequal expertise levels.

In comparison to intra-organizational projects, inter-organizational projects are significantly understudied. Project-based learning seems to be a subject, which is still full of many unanswered questions and requires the configuration of a range of learning mechanisms to be effective (Swan et al., 2010). There would need to be a sharper positioning to make it a worthwhile contribution.

The literature review chapter confirms the research question, and motivates case studies in an in-depth way. The further work will be on the theoretical underpinnings in the literature and to establish a framework for project-based learning that considers the temporary organization's project characteristics. It is suggested to conduct further research on project-based learning so that project knowledge is shared and transferred to the relevant project team members at the right time, the right place using the right medium. As a consequence, the project can be managed more effectively.

However, there are some limitations to the review. Instead of databases such as Scopus, Web of Science, or Google Scholar, the search from selective journals might have missed some relevant articles.

Appendix 3.A Quick scan of research projects on knowledge management in construction

Table 3.1 Quick scan of research projects on knowledge management in construction

Name	Full name	Time	Funded by	Lead
B-Hive	Building a Higher Value Construction Environment: Cross-organizational Learning Approach (COLA)	-	EPSRC and DETR	London School of Economics and Leeds Metropolitan University
KLICON	Knowledge and Learning In CONstruction (IT in knowledge management and organisational learning for construction projects)	1999-2000	EPSRC	University of Salford
CLEVER	Cross-sectoral LEarning in the Virtual entERprise	1999-2001	EPSRC	Loughbourough University

KnowBiz	Knowledge Management for Improved Business Performance: Improving Management Performance through Knowledge Transformation (IMPARKT)	2000-2003	EPSRC	Loughborough University
C-SanD	Creating, Sustaining and Disseminating Knowledge for Sustainable Construction: Tools, Methods and Architecture	2001-2004	EPSRC	Loughbourough University, the London School of Economics and Salford University
e-COGNOS	Methodology, tools, and architectures for electronic consistent knowledge management across projects and between enterprises in the construction domain	2001-2003	EC FP5	CSTB and University of Salford
CAPRIKON	Capture and Reuse of Project Knowledge in Construction	2003-2005	EPSRC	Loughborough University and University of Newcastle
-	A knowledge transfer approach to continuous improvement on PFI projects	2003-2004		Loughbourough University
-	An Approach to Knowledge Management for SMEs	2003-2005	DTI	Glasgow Caledonian University
PROLAB-project		2003-2005		Vaasa University (Finland)
NETLIPSE	the NETwork for the dissemination of knowledge on the management and organisation of Large Infrastructure ProjectS in Europe	2006-2008	EC FP6	AT OSBORNE
the Leonardo da Vinci Programme CLOEMC I	Common Learning Outcomes for European Managers in Construction	2009-2011	the European Commission, DG Education, and Culture	Warsaw University of Technology (Poland)
MEGAPROJECT	The effective design and delivery of megaprojects in the European Union	2011-2015	COST	University of Leeds

Appendix 3.B Source from journals

Table 3.2 Covered articles from PM journals

No.	Journals	Covered articles
1	International Journal of Project Management	89

2	International Journal of Managing Projects in Business	22
3	Project Management Journal	13
	total	124

Table 3.3 Covered articles from CM journals

No.	Journals	Covered articles
1	Journal of Construction Engineering and Management	24
2	Construction Management and Economics	19
3	Journal of Management in Engineering	15
4	Engineering Construction and Architectural Management	14
5	IEEE Transactions on Engineering Management	11
6	Automation in Construction	9
7	Building Research and Information	9
8	Journal of Civil Engineering and Management	2
	total	103

Table 3.4 Covered articles from KM journals

No.	Journals	Covered articles
1	Expert Systems with Applications	8
2	Journal of Knowledge Management	6
3	Management Learning	6
4	Knowledge Management Research & Practice	3
5	Knowledge Organization	0
	total	23

Table 3.5 Covered articles from general management journals

No.	Financial Times Top 50 journals	Covered articles
1	Academy of Management Journal	0

2	Academy of Management Review	0
3	Accounting, Organizations and Society	0
4	Administrative Science Quarterly	0
5	American Economic Review	0
6	Contemporary Accounting Research	0
7	Econometrica	0
8	Entrepreneurship Theory and Practice	0
9	Harvard Business Review	0
10	Human Relations	0
11	Human Resource Management	0
12	Information Systems Research	1
13	Journal of Accounting and Economics	0
14	Journal of Accounting Research	0
15	Journal of Applied Psychology	0
16	Journal of Business Ethics	0
17	Journal of Business Venturing	1
18	Journal of Consumer Psychology	0
19	Journal of Consumer Research	0
20	Journal of Finance	0
21	Journal of Financial and Quantitative Analysis	0
22	Journal of Financial Economics	0
23	Journal of International Business Studies	0
24	Journal of Management	0
25	Journal of Management Information Systems	1
26	Journal of Management Studies	1
27	Journal of Marketing	1
28	Journal of Marketing Research	0
29	Journal of Operations Management	3

30	Journal of Political Economy	0
31	Journal of the Academy of Marketing Science	0
32	Management Science	10
33	Manufacturing and Service Operations Management	0
34	Marketing Science	0
35	MIS Quarterly	2
36	MIT Sloan Management Review	0
37	Operations Research	0
38	Organization Science	1
39	Organization Studies	6
40	Organizational Behavior and Human Decision Processes	0
41	Production and Operations Management	0
42	Quarterly Journal of Economics	0
43	Research Policy	11
44	Review of Accounting Studies	0
45	Review of Economic Studies	0
46	Review of Finance	0
47	Strategic Entrepreneurship Journal	0
48	Strategic Management Journal	1
49	The Accounting Review	0
50	The Review of Financial Studies	0

No.	UT Dallas top 24 leading business journals	Covered articles
1	Academy of Management Journal	0
2	Academy of Management Review	0
3	Administrative Science Quarterly	0
4	Information Systems Research	1
5	Journal of Accounting and Economics	0
6	Journal of Accounting Research	0

7	Journal of Consumer Research	0
8	Journal of Finance	0
9	Journal of Financial Economics	0
10	Journal of International Business Studies	0
11	Journal of Marketing	1
12	Journal of Marketing Research	0
13	Journal of Operations Management	3
14	Journal on Computing	0
15	Management Science	10
16	Manufacturing and Service Operations Management	0
17	Marketing Science	0
18	MIS Quarterly	2
19	Operations Research	0
20	Organization Science	1
21	Production and Operations Management	0
22	Strategic Management Journal	1
23	The Accounting Review	0
24	The Review of Financial Studies	0
	Total	47

Appendix 3.C List of primary authors

Table 3.6 List of primary authors

No.	Authors	Organizations	Number of articles
1	Andrew J. Sense	University of Wollongong	8
2	Mike Bresnen	University of Warwick*	7
3	Patricia M. Carrillo	Loughborough University	6
4	Peter S.P. Wong	RMIT	6

5	Peter E. D. Love	Curtin University	6
6	Hamzah Abdul-Rahman	International University of Malaya-Wales*	5
7	Jacky Swan	University of Warwick	5
8	Harry Scarbrough	University of Warwick	5
9	Terence Ahern	Dublin City University	4
10	Catherine P. Killen	University of Technology Sydney	4
11	Derek H.T. Walker	RMIT	4
12	Terry Williams	University of Hull	4
13	P.J. Byrne	Dublin City University	4
14	Sai On Cheung	City University of Hong Kong	4
15	Linda Edelman	Bentley University	4
16	Brian Leavy	Dublin City University	4
17	Sue Newell	Bentley University & Warwick Business School	4
18	Bill Bordass	Usable Buildings Trust	3
19	Per Erik Eriksson	Luleå University of Technology	3
20	Christophe Midler	École Polytechnique	3
21	Jeffrey Boon Hui Yap	Universiti Tunku Abdul Rahman & International University of Malaya–Wales	3
22	David Arditi	Illinois Institute of Technology	3
23	Tim Brady	University of Brighton	3
24	David J. Edwards	Birmingham City University	3
25	Robert A. Hunt	Macquarie University	3
26	Per-Erik Josephson	Chalmers University of Technology	3
27	John E. Taylor	Georgia Institute of Technology	3
28	S. Jonathan Whitty	University of Southern Queensland	3
29	Stephen Duffield	University of Southern Queensland	3
30	René M. Bakker	Tilburg University*	2
31	Chantal M.J.H. Savelsbergh	Open University of the Netherlands*	2

*when the article was published

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Chapter 4 Efforts on Explicating Knowledge in the Project-based Setting: an Overview of the Facilitating Role of the Project Case Base

Abstract

Learning in large infrastructure projects is partly and often based on ex-post evaluations of past projects. However, many lessons from past projects have been lost, and it is vital to find a way to share insights. There has been no systematic overview of project case bases in practice to date, raising the question of what is the current status? Using the method of fieldwork and content analysis, this study offers a comprehensive overview of seven main project case bases set up by the academia or the market. It is found that the popularity of project case bases is increasing, with a majority emanating from Europe and North America. Besides, some emerging issues mainly related to operation types, adopted methods, the scope of data collection and analysis, and limited access to project data, are identified. The research then discusses the limited value of current project case bases. This study helps provide construction and project management academics and practitioners with a more comprehensive overview of the development and application of project case bases and implications for future studies.

Keywords: Project case base; knowledge management; project management; codification

4.1 Introduction

Major projects can be understood as temporary endeavors with predefined tasks and end dates that need to bring together a changing cast of multiple participants capable of delivering the outputs, outcomes, and resulting benefits over lengthy periods. The actions required to process information to deliver project tasks are always situated in a specific context, characterized by varying degrees of complexity and high levels of interdependency amongst project participants.

The ability to exploit existing knowledge is crucial to this process. Projects have access to static explicit knowledge captured in knowledge management systems, databases, and large volumes of tacit know-how knowledge of all the individuals and organizations brought together to deliver the project. Due to the uncertain nature of major projects and the need to enhance the value to be created, they are often required to explore new knowledge from other successful and unsuccessful projects as the project progresses through the life cycle. The project needs to convert explicit and implicit knowledge into repeatable and recognizable patterns of interdependent action by multiple participants to embed it in organizational processes and routines to become capable overtime in that particular situation.

Until now, there is a path dependence that when construction managers establish a plan, they refer to historical data first mainly by reacting on data mostly built up from incidents. And then, they adjust somewhat by their own experiences. It is particularly attractive to capture the success stories from project-based work and to adapt them to the appropriate context in other projects and the broader organization (Kerzner, 2018). These best practices can significantly refine existing methods and offer new and flexible solutions to solve problems and complete tasks.

Finding better ways of accessing project knowledge about infrastructure development is proved to be necessary and urgent. Business case study research has been mostly carried out (Dul and Hak, 2007; Farquhar, 2012), but the methodology of using the international infrastructure project case base is given less importance. Williams (2003) found that project review processes were rarely used to analyze project success and failure in practice. Consequently, the significant challenge is how to effectively manage the "database" and extract useful knowledge and information flexibly and accurately.

The problem can be twofold: a) the codification of knowledge is not done properly or not done at all; b) there is knowledge stored one way or another. However, the project teams cannot use this knowledge in the right way for their next projects because the project manager puts forward his own subjective experience. Therefore, we ask: what is the current status quo of project case bases in practice? Sub-questions can help further break down the overarching question into manageable parts that will be addressed in order to unravel the problem. What proper lessons learned systems are currently available? What kinds of methods do they use? How large are the areas covered? What is the impact of the work? Once we obtain enough high-quality data of projects, can we predict a new project's performance? And

so on.

In this research, we present a comprehensive overview of previous and current seven project case bases in storing, mining, and disseminating best practices and lessons learned in large projects and investigate the effectiveness of this approach.

4.2 Related work

4.2.1 Knowledge codification

Learning gained from working together in the project can be identified to back up our decisions and solutions to solve problems effectively. It can occur in a codification way through decontextualizing knowledge so that knowledge can be represented and communicated explicitly (Ruggles, 1997). It was predominantly done by producing learning documents at the end of the project, which could be used as starting documents for the next project teams. The codification way emphasizes collecting knowledge and saving it in books, manuals, and an electronic database, so that knowledge can be in everyone's reach (Gammelgaard and Ritter, 2005). Individuals can learn from the codified best practices and lessons learned from a broader IT system source without having to rely on their personal or shared experiences (Newell, 2009). From the transfer of content, some explicit knowledge about both previous project decisions and solutions, and their outcomes and project performance are diffused through post-project appraisal, after-action review, micro-articles, learning histories, and other forms of solidification for other projects (Schindler and Eppler, 2003).

Project teams often use their historical documentation or best practices as a template, so they do not have to start from scratch (Zhang et al., 2015). The most common approach used in the large infrastructure projects to capture, store, and disseminate the learning from projects is a database for others to access (Newell et al., 2006). Project histories are repositories/databases that contain useful information and knowledge from previous projects. This is usually conducted individually by project parties. With the IT development, explicit knowledge can be easily managed by implementing those technologies, which push forward the codification strategy of the knowledge. The codification of knowledge is a mechanism for the creation of explicit knowledge. There are lines of research focusing on developing methodologies to capture and reuse the knowledge created and lessons learned in projects (Buttler, 2016; Kivrak et al., 2008).

Similar projects lead to similar approaches to their delivery. The codification of projects describes project management as a standard set of processes and knowledge areas, such as procurement management, time management, cost management, and risk management. The knowledge codification in projects implies that projects are similar to some degree and have a certain level of similarity in the processes. So, the information from the codification is relevant to most projects, most of the time.

However, more and more literature and practices argue that project management is embedded within an ever-increasing range of unique contexts (Fernie et al., 2003). Understanding contexts becomes central to the knowledge sharing and transfer processes.

4.2.2 Project case and business case

Many cases, rather than the single one, strengthen the results significantly and manifold. The project database tries to involve gathering a large set of data from cases so that statistical analyses can be performed on the variables, helping to mobilize previously dormant case study knowledge to foster in-depth thoughts. We argue that the database can facilitate the cross-case analysis and arrange the knowledge systematically.

Many business schools like Harvard Business School, Ivey Business School, and INSEAD have been devoted to developing and utilizing case studies on the business contents. However, project cases are different from enterprise business cases. Gathering the project-specific data is essential to be able to use the project case for benchmarking, comparisons, learning, and training, consultancy, and case studies.

The project-specific data can be related to two levels of results: the project output and project outcome. The project output refers to the new asset delivered from a project and may consist of multiple deliverables. These deliverables are usually tangible, and their production can be controlled and guaranteed. On the other hand, project outcomes refer to the target benefits the operation of that asset gives. As compared with project outputs, project outcomes are usually intangible, and their realization cannot be guaranteed. This means that a project's target outcomes will typically be realized sometime after project outputs are delivered. The output is evaluated as the project management efficiency and success (Al-Tmeemy et al., 2011; Roger and Atkinson, 1999). The project outcome creates the business sense and pays attention to the impact on the client, stakeholders, and business success (Mir and Pinnington, 2014). Compared with the business cases driven by the customer's outcomes in the business school, project case bases focus more on the outputs of the project process. Interpreted from earlier work, infrastructure project cases regarding project management have the following three characteristics:

1, Intangible nature of deliverables. The ideas and intentions carried in the drawings and project management plans are intangible. Its quality evaluation is difficult to measure with objective indicators (such as numerical values), compared to evaluating the quality of the physical asset.

2, Professional, and highly intelligent process. The process of project management uses intellectual knowledge, and there will be some creativity, which is different from factory production.

3, Being customized for the owner. The project management service is customized for the owner and requires the full participation of the owner.

From the essential characteristics, there are some difficulties in project management:

1. Supervision difficulties. The ideal control requires that outcomes can be objectively measured, behaviors can be observed, the link between effort and outcome is established, and the owner has the relevant knowledge to control the relationship. However, it is challenging to monitor project management.

2, Joint-working. Since project management is the result of the joint efforts of the owner and the project team, the efforts of the project team do not necessarily mean good project management results. This means that the link between the project team contribution and the project quality might be rather vague.

The project output is available immediately after the project is executed, and there is a delay in project outcome after the execution of the project (Zwikael and Smyrk, 2012). The current project case bases almost all collect the information from project output. It is necessary to consider project performance over time: project management success but deliverable failure, and project management failure but deliverable success (Ika, 2009).

4.3 Research methods

A number of characteristics of post-project reviews have been identified, but no previous study has consolidated our understanding. There are earlier efforts in creating a project database. The following section provides an overview of several databases with a short description of each of them. There are other still on-going databases such as CII (Construction Industry Institute) Knowledge Base, the Major Projects Knowledge Hub, ICCPM (International Centre for Complex Project Management) and the Stanford Global Projects Center (GPC), and inactive ones such as GIPRN (Global Infrastructure Project Research Network). They are not taken into account because of limited access to their in-depth data and lack of public information.

Information about the following project case bases was collected mainly from their official websites and public reports. The data were collected by buying and reading carefully leading publications written by projects case bases staff (Flyvbjerg and Hertie School of Governance), carrying out exploratory interviews with representative informants (NETLIPSE, Cost Action Megaproject, and MPCSC), attending the workshops held, and participated by project case bases (NETLIPSE and COST Action Megaproject), and visiting some of their offices (OMEGA Centre and MPCSC).

4.4 Debriefing project case base in the overview

4.4.1 IPA

IPA (Independent Project Analysis) is a private international benchmarking, research, and consulting corporation headquartered in the US and was founded by Edward Merrow in 1987.

IPA has a structured and extensive database of capital projects and consisting of more than 21000 benchmarked projects, and over 600 tracked annually distributed around the world with the project size ranging from about $100 thousand to approximately $40 billion (Merrow, 2011). However, the data from these projects are not publicly available.

The research from IPA as a company resulted in three books: "Industrial Megaprojects: Concepts, Strategies, and Practices for Success," "Capital Projects: What Every Executive Needs to Know to Avoid Costly Mistakes and Make Major Investments Pay Off" and "Leading Complex Projects: A Data-Driven Approach to Mastering the Human Side of Project Management."

More information can be found on the website: https://www.ipaglobal.com/

4.4.2 NETLIPSE

NETLIPSE (the NETwork for the dissemination of knowledge on the management and organization of Large Infrastructure ProjectS in Europe) started as a two-year research program (2006.5-2008.5) supported by the European Commission Sixth Framework Programme (FP6) to make a comparative analysis between different sizeable European infrastructure projects. Fifteen large infrastructure projects throughout Europe were investigated, culminating in publications such as “Managing Large Infrastructure Projects: Research on Best Practices and Lessons Learnt in Large Infrastructure Projects in Europe.” Afterward, the European Commission TEN-T (Trans European Transport Network) Executive Agency provided funding to continue and expand the NETLIPSE initiative (2008.6-2010.12). The “Infrastructure Project Assessment Tool” (IPAT) was developed. Since 2014 the network has decided to continue as an informal network financed by several public organizations with formal agreements on cooperation between participating organizations. The system's focus remains knowledge exchange and development, which is supported by network meetings, research initiatives, project leaders’ seminars, training, and IPAT assessments. It is currently the only client-based network. Project managers and directors share knowledge informally and formally in the non-profit but engaging community.

More information can be found on the website: http://www.netlipse.eu/

4.4.3 OMEGA Centre

The OMEGA Centre for Mega Projects in Transport and Development is based at the Bartlett School of Planning at University College London (UCL). It was set up funded by the Volvo Research & Education Foundations (VREF) in 2005 for five years and engaged in various aspects of the planning, appraisal, and delivery of mega transport projects (MTPs) worldwide. The research is done by currently making available publications such as the Routledge-OMEGA Book series on Mega Infrastructure Projects. The OMEGA Centre is still organizing many workshops and seminars on different topics.

More information can be found on the website: http://www.omegacentre.bartlett.ucl.ac.uk/

4.4.4 COST Action MEGAPROJECT

MEGAPROJECT (the Effective Design and Delivery of Megaprojects in the European Union) is a network of over 80 researchers from 25 countries (2011.5-2015.5) that were working together to improve the design and delivery of megaprojects across sectors in Europe funded by COST (European Cooperation in Science and Technology) Action.

COST Action MEGAPROJECT has collected over 50 European megaprojects' experiences and worked on seeking patterns from excellent or lousy delivery performance. They gathered together a group of 30 cross-sectoral cases into the MEGAPROJECT Portfolio. This is an open-source, freely available group of examples accessible on the official website in a standardized format. Users can search results with keywords on sectors, country of location, ownership (public/private/mixed), prime contractor, size, start date, and performance (schedule and cost). This openness can promote a learning effect on megaproject performance and benchmark for European megaprojects.

More information can be found on the website: http://www.mega-project.eu/

4.4.5 Flyvbjerg's database

Professor Bent Flyvbjerg and his colleagues developed a project database consisting of 258 transportation infrastructure projects distributed over 20 countries, including both developed and developing nations and regions (Flyvbjerg et al., 2003). After that they have enlarged the original international database to 806 projects (Cantarelli et al., 2012). The main objective of developing this database is to propose a method for increasing the accuracy of project cost estimation. Flyvbjerg introduced a new technique called RCF (reference class forecasting) for achieving the accuracy of cost estimates based on the actual performance in a reference class of comparable projects (Flyvbjerg et al., 2005). Based on his database, Flyvbjerg concluded that there are two potential explanations regarding the inaccuracy in cost estimations and corresponding cost overruns in infrastructural projects, namely optimism bias and strategic misrepresentation (Flyvbjerg, 2008).

4.4.6 Hertie School of Governance

Professor Genia Kostka and Professor Jobst Fiedler from Hertie School of Governance in Germany investigated 170 large public infrastructure projects in Germany, including the building, transportation, defense, energy, and ICT sectors. Projects are analyzed on their scale, patterns, and causes of cost overruns. Among these projects, 119 were finished between 1960 and 2014, and 51 are currently still under construction. Three detailed case studies on the Berlin Airport BER, the Elb Philharmonic, and Offshore Wind Parks are picked up for detailed investigation (Kostka and Fiedler, 2016). The research published the book "Large infrastructure projects in Germany: Between ambition and realities."

More information can be found on the website: https://www.hertie-school.org/en/infrastructure/

4.4.7 MPCSC

MPCSC (Mega Projects Case Study and Data Center) is the case database developed by the Research Institute of Complex Engineering and Management at Tongji University China in 2014. The center collected case data on 67 skyscrapers, 11 stadiums, 12 bridges, 8 energy bases, 51 power plants, 5 airports, 41 high-speed railways, 6 highways, 5 ports, 2 tunnels, 39 transportation hubs, and 146 metro lines (accessed on April 30, 2020). It is funded by Tongji University and National Natural Science Foundation of China.

More information can be found on the website: http://www.mpcsc.org/

4.5 Emerging issues of project case bases

4.5.1 Operation types

Table 4.1 shows several characteristics of the above project case bases. They exist in diverse forms and for various reasons. More than half are initiated with public funding, for example, COST Action Megaproject funded by the EU Framework Programme and MPCSC funded by National Natural Science Foundation of China. OMEGA Centre was established with support from the private sector but later run by the university. IPA has been operated as a business company all the time. It provided the highest level of access to benchmarking of both large and site-based systems to more than 80 member industrial companies in its industry benchmarking consortium (IBC) established in 1992. NETLIPSE is now led by the industry client partners and run in the form of a community.

Table 4.1 Characteristic of the project case base

No.	Project case base	sponsors	location	leader	Existing period	Number of projects	publicly available
1	IPA	IPA	the US	Edward Merrow	1987-now	20000+	No
2	NETLIPSE	Firstly EC FP6 and then client organizations mainly in North-West Europe	Europe	Marcel Hertogh, Eddy Westerveld & Pau Lian Staal-Ong	2006-now	17 (shown in its website)	Yes
3	OMEGA Centre	Firstly the Volvo Research & Education Foundations (VREF) and then UCL	the UK	Harry Dimitrou	2006-2011	30	Yes
4	COST Action	EU COST Action	Europe	Naomi Brookes	2011-	50	Yes

	Megaproject				2015		
5	Flyvbjerg	-	The UK	Bent Flyvbjerg	-	806	No
6	Hertie School of Governance	Hertie School of Governance	Germany	Genia Kostka	2015	170	Yes
7	MPCSC	Tongji University and National Natural Science Foundation of China	China	Zhaohan Sheng	2011-now	393	Yes

The project-based work results in a lack of continuity and thus hinders the building of capacity for learning. Project case bases should be long-lasting. Without constant support from real projects, they will atrophy due to infrequent use. Project case bases are knowledge hubs created for projects. However, many of them are not able to avoid becoming "projects." After the funding period, COST Action became inactive, while NETLIPSE adopted a new operating model. They all face the challenge of maintaining and making use of the case base in a sustainable way.

These project case bases focus very much on learning from experiences in practice on how to manage large infrastructure projects. On the one hand, they try to collect as many cases as possible so that statistical analysis (benchmarking) can be done. They provide an excellent experience for most projects most of the time. On the other hand, some individual iconic projects are elaborated to open the black box of megaprojects and their impact over time. For example, the Berlin Airport BER case were described in depth by Hertie School of Governance (Kostka and Fiedler, 2016).

Among these seven databases, three of them only focus on infrastructure projects (NETLIPSE, OMEGA Center, and Flyvbjerg). Others (IPA, Cost Action Megaproject, Hertie School of Governance, and MPCSC) have a spectrum of projects from other industries such as energy, oil & gas, food, and pharmaceuticals.

4.5.2 Scope of data collection

All projects are executed in different contexts. The complexity is described by using two perspectives, one using the Technical, Organizational, and Environmental framework (Bosch-Rekveldt et al., 2011), the other using a distinction in "detail" and "dynamic" complexity (Hertogh and Westerveld, 2010). There are many obstacles to accuracy, such as selecting the sample, size of the sample, bias, collecting the data, and commercial secrecy. It leads to the notion that project case bases cannot control their data to the full extent. It is questionable if we can benchmark.

Some project case bases focus on projects that occur in a single region or country (German projects in Hertie School of Governance and Chinese projects in MPCSC). It can be seen that Europe has many

project case bases. All of the data within COST Action Megaproject has been obtained from European megaprojects, so does NETLIPSE. OMEGA Centre studied 30 mega transport projects in ten developed regions, including the UK, France, Greece, Germany, The Netherlands, Sweden, USA, Australia, Hong Kong, and Japan. Although such project case bases report on essential findings and are valuable to a regional audience, they are not well-suited to the global audience. This makes it difficult for other international projects to learn from these case bases because of the differences in the context, such as political, legal, social, and economic considerations. It lacks an internationally recognized community structure that other continents enjoy in this field of research.

In real life, intuitiveness and easy-to-compare reference points play a more critical role in the evaluation and often have a more significant impact on our decisions (Dane and Pratt, 2007; Heath et al., 1999). When it was checked which data to capture, quantifiable and hard measures of the project management (cost and schedule) have been found as the first response by most project case bases. One criticism of the Flyvbjerg database is that it only focuses on the cost performance of projects. Some project case bases apply merely the "iron triangle" parameters in their assessments and identify the factors leading to this defined success. Many project management researchers have reached a consensus that the classical mindset of judging the project merely based on the iron triangle (schedule, budget, and quality) neglecting that other criteria are also critical (Lehtonen, 2014) is too simple and cannot capture all aspects of contemporary megaprojects.

Due to the megaprojects' uniqueness, it is difficult to gather good practices and systematically develop empirically-based guidelines. The OMEGA Centre and NETLIPSE take the broadest view, highlighting the role of context in success perception. The OMEGA Centre's research suggests that there is no generic definition for project success, and it is highly dependent on the specific context of the project. According to Miller & Lessard (2001: 15), "effective projects can generally survive their inefficiencies (cost overruns, late completion, or early operational problems), but ineffective projects cannot compensate for their failures by efficient project execution." Many examples are achieved with schedule delay and cost overrun, but time proves they are successful projects. There is evidence that the megaprojects that focused more on the project constraints missed the value creation to a more considerable extent (Pitsis et al., 2018). Therefore, it is joyful that these project case bases can take a look at megaprojects with a longer time horizon and as a long-standing organization.

4.5.3 Limited access to project data

The proper data gathering structure for success and failure behavior and performance of projects is a key, however, complex issue. The operation of these project case bases was observed because it was expensive and inefficient to get access to data, touching on poor data management, data ownership, and the willingness of parties to cooperate. Lehtonen (2014b) argues that the evaluation's main objective is merely accountability rather than learning and adapting them to the specific contexts.

Current construction information and knowledge are scattered and fragmented across regulations, paper forms, recoding systems, engineers' and managers' experiences (Zhang et al., 2015). Explicit knowledge can be stored. It is concrete, formalized, and transferrable. Most of the construction firms have invested in building their ERP (Enterprise Resource Planning) systems in the last few decades. However, proprietary data was owned independently by separate project parties, and no cross-referencing or searching was made possible. Technological constraints do not permit limited data to be managed and shared. Knowledge is prone to free-riding because of the non-exclusive nature of knowledge that others can easily copy and paste. Cooperation means knowledge and information sharing but considering the possibility of losing core competence or leaking commercial secrets, providing data to a database that is owned and managed by other parties causes the reluctance of participants.

The free flow of information is limited in megaprojects. Tacit knowledge cannot be stored. It is rooted in an individual's experiences, expertise, and abilities; it is more challenging to communicate. From an organizational perspective, summarizing successful and unsuccessful experience is not part of project performance evaluations. From an individual's perspective, people tend to share good practices, not project failures, and mistakes. In some project case bases, we heard difficulties to get the data and in-depth information on formal channels such as databases, platforms, and reports. Project managers took transient actions, and decentralized organizing of projects with multiple partners and stakeholders make these formal approaches for learning problematic. Converting tacit knowledge into explicit knowledge is seen as a significant challenge for project case bases.

4.5.4 Adopted analysis methods

There is a database, but the data is rough and needs to be cleaned up to be useful for further analysis and visualization. Eisenhardt (1989) developed the process of inducting theory from reviewing a set of cases of a particular phenomenon to generate theoretical generalizations. The transformation from raw data to usable information is often dependent on human action; it does not transform by itself. For the current project case bases, we foresee two trajectories, either they focus on in-depth single case studies with less ambition to generalize elsewhere (e.g., NETLIPSE and OMEGA Centre), or they cover a large number of projects. However, they do not pay extra attention to details (e.g., Flyvbjerg's database and MPCSC).

The main trajectory is to build more massive data sets in order to enable benchmarking. Quantitative studies have also been carried out based on the analysis of benchmarking data among projects. Some project case bases such as IPA develop large-size databases and algorithms about projects covering various aspects of projects in statistical models. This statistics-based methodology provides efficient, good quality information sharing and learning motivation. Benchmarking can support project management by comparing with others' best practices and by continuous improvement within the organization. The inductive cross-case analysis takes a similarly constructed cross-case comparison and uses a structured process (Brookes and Locatelli, 2015). Greater attention is paid to the variables across

cases. The complexity and context of individual cases are not at the center. They use mathematical models and algorithms to arrive at empirically valid patterns. However, the focus does not lie in formulating management problems.

The second trajectory responds to the on-going call to explore megaprojects in depth from various angles to increase our understanding of the interconnected organizational elements of megaprojects in their broader institutional and cultural contexts (Söderlund et al., 2017). We find that a wide range of qualitative methods and data in project case bases was used, such as narrative storytelling, interviews, and inductive archival analysis. Qualitative and quantitative methods and data fulfill different but complementary needs in project case bases. Qualitative approaches play a more critical role, especially in some situations where project-specific data are highly confidential due to commercial and political reasons. This project case-based research may benefit insights and ways to zoom in on the practical actions and interactions. However, it seems to be subjective to the assessors' views and their experience. It is not the mainstream in the project case bases.

A real phenomenon that can be observed is that some novel research approaches or tools in studying major and mega projects are developed in using the above project case bases. The IPAT® (Infrastructure Project Assessment Tool), a NETLIPSE-product, addresses how the Project Delivery Organisation (PDO) and Client/Sponsor (C/S) manage and plan to manage all relevant aspects of a Large Infrastructure Project. Flyvbjerg et al. (2003) have applied RCF (reference class forecasting), a method intended to reduce optimism bias, to public planning of infrastructure projects.

4.5.5 Once-off or on-going evaluation?

The unit of analysis in project case bases needs to be clarified. Project output or performance refers to what will be delivered by a project and may consist of multiple deliverables. These deliverables are usually tangible, and their production can be controlled and guaranteed. On the other hand, target benefits or project outcomes refer to the objectives we aim to achieve with a project. As compared to project outputs, target benefits or project outcomes are usually intangible, and their realization cannot be guaranteed. This means that a project's target outcomes and benefits will often be realized only sometime after delivering the project outputs (Turner and Zolin, 2012).

The project case base's data is typically from the records gathered after the project, which is also called the ex-ante assessment. Project control with schedule and cost pressures does draw attention to taking a breath to reflect. The summative evaluation takes a retrospective look back on a project after it has been finished. However, learning by project assessments until after project completion seems too late. Project-based organizations focus more on completing the projects and rushing to the next one rather than on the quality of project-based learning and reflection (DeFillippi, 2001).

In the setting of project management, several participants work together during the realization of the project and spread out after the end of the project. The knowledge generated during the execution of the project has a collective but volatile dimension. Figures and facts collected in a project are not sufficient to keep track of the created knowledge. The dynamic character of knowledge owes to collaborative problem solving where various ideas are confronted with building a solution. Knowledge and experience during the project may be lost due to a change of staff or just forgotten. Learning between projects is also challenging when the time jumps are so big. However, through reading documents in these project case bases, many cases in the project case bases do not well record early recollections. The evaluation is only a snapshot at the end of the project.

4.6 Discussion

It is challenging for project-based firms to systematically learn from project to project because it is still tough to gather lessons learned from these projects in a systematic structure and methodology to reach the same goal.

4.6.1 Issues in project case bases

Based on the information provided and analysis of project case bases in previous chapters, we sum up the following issues:

1, Presence of data on which to base reasonable learning.

The difficulties in achieving this activity are created by the inherent nature of the projects themselves. The nature of the AEC industry is characterized by experiential knowledge since knowledge is highly based on individuals' experiences and perceptions, which increases the difficulty of capturing and reusing it (An and Ahmad, 2010). Besides, large infrastructure projects with a myriad of participants engaged in a network of interrelationships are incredibly complex. They are embedded in a wide supply chain in decade s' long lifecycle, hindering the exchange of knowledge and co-learning culture. Large infrastructure projects' size and complexity make it very difficult to discern which actors and elements of its myriad configurations have actually influenced performance. Large infrastructure projects' experience is even more unique than that of smaller projects, making the number of comparable large infrastructure projects extremely small. This results in the difficulty of ensuring the knowledge's accuracy and correctness and will require considerable effort and time.

However, current project case bases fail to take good account of the complex contexts and disparate perspectives in the AEC industry. There is still significant work required in learning in order to move to a more sophisticated and holistic approach.

2, The mechanisms to make learning available.

The reason the European Commission first sponsored the NETLIPSE initiative in 2006 is the fact that there was not enough knowledge sharing across the geographical borders of large infrastructure project experiences, and certainly not on an owner level. The complexity calls for various methods to be adopted to investigate the mechanism within these projects. The ability to learn across large infrastructure projects becomes even more challenging (Hertogh et al., 2008).

In the AEC industry, it was argued that lessons learned are often viewed as a saleable commodity and not widely shared (Carrillo & Chinowsky, 2006). However, few project participants have institutionalized lessons learned in their routine. Therefore, experience, especially lessons learned, is often forgotten in the project organization memory, and problem-solving continues to rely heavily on individual experienced engineers and project managers' expertise.

Only when the sample size reaches the tipping point can statistically significant relationships be confidently identified. This is problematic for most cross-project learning, as there are not that many of them. To enable data to be reused for project management, it seems more likely that single and independent parties should manage proprietary project data.

4.6.2 File and forget?

At present, the development of a database for sharing various project knowledge and information is very good at reducing information asymmetry and reducing search costs, thus making knowledge matching more efficient. In our research, a limited number of for-profit consulting firms and professional associations such as IPA and CII or not-for-profit organizations such as NETLIPSE and MPCSC have collected positive and negative lessons from several past projects and offered benchmarking assessments.

According to the above issues, the current project case bases are far from satisfactory. It is not because capturing and disseminating knowledge is not done enough; knowledge management has advanced dramatically in recent years. Instead, it is reported as a lack of access to the implicit assumptions behind some of the information and the lack of enough data to validate it. The knowledge is present in the form of codification but will not be appropriately used by the new projects.

Even though megaprojects may last many years as a mini-company, they are temporary in essence and disperse after completion. To deliver a construction project, people are brought together, often for the first time, to achieve a common goal. Project managers for megaprojects may not finish more than one or two such projects in their lifetime. The project is a temporary framework for learning, and when the project is completed, the people disperse. Unfortunately, such valuable experience and specialized knowledge that is being created every day on projects have been stored only and mainly in the minds of individual experienced engineers and project managers. It is generally not easily shared with junior engineers and project managers.

Moreover, when experienced engineers leave or retire from the project, their valuable tacit knowledge is lost as well. In Shell, a process called Retention of Critical Knowledge (ROCK) was developed as process for this. Project managers and directors were interviewed before they left or retired. The interviews was videotaped to get as much tacit knowledge from them as possible. The benefits are in the long term. However, knowledge management has received less attention in the project-based AEC sectors. What was known and learned, often with great difficulty, during that project is then "forgotten" by the organization, if not the individuals. It has been apparent that many people involved with these projects have been unaware of the need for structuring the information for future use. Therefore, it is problematic to create a knowledge platform or database.

Because personal experience has its congenital disabilities, such as distorted knowledge because of subjectivity, inaccurate empirical knowledge due to memory, limited personal interviews can only reveal a part of the project. Excessive reliance on personal experience is also detrimental to the long-term development of the project case base. The loss of historical project data is roughly common in three situations: the original data is lost; the original data cannot be transformed into repeated useful information; the valuable information is fragmented over different parties.

Due to a limited number of cases, conclusions may be drawn with the effects of survivorship bias and success bias. Each project has its history, background, location, and characteristics, so imitating those distant winners or taking those distant losers' lessons learned may not have much effect. Individually and temporally, they are successful or unsuccessful but local. The database implies consistency across the sector. This is not happening as far as we can see. If only the characteristics of successful projects are summarized, then we cannot rule out the possibility that future projects also follow these characteristics. It is the first step to adequately sum up causality when putting successful and failed projects together.

4.6.3 Recommendation for knowledge personalization

A stream of literature builds on the work of Flyvbjerg et al. (2003) arguing that we are unable to continuously learn from one megaproject to another and internalize the knowledge (Sengupta et al., 2008). The above investigations and discussions on project case bases worldwide have shown that many post-project evaluations have been done in the way of codification. Learning after completion can bring new perspectives. It is still the primary and most important learning tool to capture project knowledge (Carrillo et al., 2011). Past efforts are spent on ex-post remediation instead of ex-ante prophylactic or proactive measures.

However, emerging issues of current project case bases have restricted them from achieving more value in the project-based sector. Establishing a database system will not automatically generate a learning environment or lead to greater understanding. This knowledge management considers the interplay

between knowledge as a stock category and deals with known knowns. We call for more proactive learning as a flow category. Hartmann & Doree (2015) argued that it is rather simplistic to have a more traditional sender/receiver perspective on learning. The sender/receiver perspective assumes knowledge as a transferable commodity and learning to transmit knowledge between the sender and the receiver in projects. They suggested observing progress and social interactions as a tool in understanding and enhancing project learning activities. Learning helps us notice known unknowns and unknown knowns. This chapter confirms the learning issues found in the review of codification in Chapter 3 and calls for a more focus on social interactions and in-depth case studies. More research on emphasizing the acquisition and disseminating of knowledge through social processes is carried out in the following three case studies.

4.7 Conclusion

Learning gained from completed and on-going projects can be a valuable asset to a project-based construction organization. Repeated studies have shown the limitations of a sender/receiver model of knowledge transfer (Hartmann and Dorée, 2015). Knowledge is seen as general, abstract information that exists independently of the setting. The current kind of project case base focuses on figures and facts mixed up with the different data types with limited accessibility. It gives some general conclusions but is not enough to inspire the practitioners in their daily work. Learning has become synonymous with knowing but knowing is far from real learning. The loss of knowledge within and across projects has far-reaching implications for performance, productivity, and competitiveness for project participants and project-based organizations.

Each project is different, but many projects are similar. The project case base can provide project teams with the knowledge and experience they need to impact the ultimate success of both projects and project management. Using an in-depth comparative case study of actual projects, the project case base can better contribute to project management practice theory and give evidence-based recommendations to practitioners. Current post-project review activities are not very successful in spreading knowledge to other projects and parent organizations. The project case bases described above suggest that although a regional case base can be found and much is being done in the area of knowledge management in construction, the core issue of the knowledge transfer between large infrastructure projects on an international scale is still not being addressed. The creation of knowledge can be a by-product of practice. However, the project case base's goal is not only to describe the cases but also to change them in the future. The learning potential of large amounts of project data collected by project-based organizations is insufficiently exploited. Few studies to access case-based comparison are not holistic, lack empirical support, and are based on weak credentials. The data should be made available to partnerships between academia and practice. New actions are needed to use these databases for learning.

To understand the causes and effects, and estimate the probability of the practical problems, and prepare an emergency plan for similar issues, it is necessary to fine-tune the ability to learn within and across projects. The project case base should not only be seen as a repository of explicit knowledge but more accurately seen as the product of tacit knowledge. The future work lies in looking at what people do and not why people do it. More details will be revealed in the following three case studies.

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Chapter 5 The Co-creation of Values-in-use at the Front End of Infrastructure Development Programs

Abstract

There has been recent academic interest in programs as value creation processes. Scholars focus particularly on the front end of programs as opportunities for clients to create value. At the front end, client and market partners can actively co-produce value through co-creation sessions. This research investigates what stakeholders do in co-creation sessions and how this contributes to the co-creation of value at the front end of programs. We used an action research approach combined with participant observation, document analysis, and interviews with participants to study stakeholder engagement in co-creation sessions at the front end of a Dutch infrastructure development program. The findings show that the client intended to realize a value (value-for-firm) that was competing with market partners' values. By engaging in co-creation sessions with the client, market partners and knowledge partners co-created three sets of values (value-in-use) as follows: commercial, intellectual and collaborative values. The findings contribute to the academic debate on value creation in programs with an in-depth understanding of co-creation sessions at the front end.

Keywords: Co-creation, value creation, front end, program, action research, infrastructure development

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5.1 Introduction

Increasing academic attention has been devoted to fully understanding the value creation process in the context of programs (Martinsuo and Hoverfält, 2018; Thiry, 2004, 2002; Winter and Szczepanek, 2008). A program is defined as "a group of projects which contribute to a common, higher order objective" (Turner, 2014: 324). Programs are often regarded as large-scale projects (Morris, 2013), as strategic and long-term undertakings (Pellegrinelli, 2002) and as complex and uncertain endeavours (Artto et al., 2009). Although the conceptualization of programs in the project management literature has been diverse over the years, scholars have come both to cherish the value-oriented, integrated multi-project character of programs and to understand their context-specific management requirements (Martinsuo and Hoverfält, 2018).

A program's front end is primarily understood to be important in the sense-making of stakeholders' needs and in the specification of the benefits and values that programs are intended to deliver (Thiry, 2004, 2002). At the front end of programs, the tensions, and interests of stakeholders can be identified to define and determine the value of programs (Thiry, 2004). The value creation process is understood to be related to the source and target of value creation (Lepak et al., 2016), which has two sides: the firm and the user (Gupta and Lehmann, 2006). Value-for-firm is the value that a firm has realized, while value-in-use is realized when the user uses a product or service (Grönroos, 2011; Vargo and Lusch, 2008, 2004). Value creation is thus seen as part of a process in which stakeholders work together and influence one another, creating opportunities for synergy (Gardiner, 2014). This draws our attention to the practices and mechanisms through which values are bestowed upon objects and services (Larsen, 2015).

There has been scant emphasis on the importance of co-creation sessions at the front end and of programs for creating value (Keeys and Huemann, 2017; Näsholm and Blomquist, 2015). Co-creation can be described as an interactive practice in which users actively contribute their ideas to create - jointly with suppliers - value to an object (Prahalad and Ramaswamy, 2004). In program studies, co-creation has been explored as a strategic approach to programs (Mills and Razmdoost, 2016; Näsholm and Blomquist, 2015). They stated that co-creation could help harness creativity and engagement in programs and better adapt to changing stakeholder expectations and learning from each other. Although co-creation has been explored as a strategic approach to program management (Mills and Razmdoost, 2016; Näsholm and Blomquist, 2015), its contribution to or limitations of value creation in programs' front end remains underexplored (Smyth et al., 2018).

With this research, we respond to the call for a deeper understanding of value creation at the front end of programs (Martinsuo and Hoverfält, 2018; Smyth et al., 2018; Winter and Szczepanek, 2008). Martinsuo and Hoverfält (2018) emphasized the importance of studying value creation in programs and name this one of the most promising research directions in program studies. Therefore, this study

investigates what stakeholders do in co-creation sessions and how this either contributes to or limits the co-creation of value at the front end of programs. Formulating our aim into a question, we ask: *How does co-creation contribute to or limit the creation of value at the front end of programs*?

To answer this query, we draw from an in-depth case study of co-creation (learning) sessions at the front end of the MultiWaterWorks (MWW) program, a large program of Rijkswaterstaat (RWS), the executive body of the Dutch Ministry of Infrastructure and Water Management, for the replacement and renovation of 52 ship locks over the next 30 years. An in-depth case study is an excellent research method to understand organizational complexity (van den Ende and van Marrewijk, 2019). We selected the case based upon a set of criteria: the size of the program, the focus on the front end, and the access and focus on value creation in which stakeholders participated equally. We adopted an action research methodology (Delhi, 2003) that included participant observation during four co-creation sessions and executed interviews with 14 participants to collect data. The findings in this study show that co-creation sessions generated three sets of value-in-use: commercial, intellectual, and collaborative values. The academic contribution of these findings to program studies is threefold. First, we respond to the academic call for understanding value creation at the front end of programs (Martinsuo et al., 2019) with an in-depth study of co-creation sessions. Second, we used literature on firm-user interaction for product and service value creation (Goel and Yang, 2010; Gosselin and Bauwen, 2006) to theorize the co-creation process in programs and identified three sets of value-in-use co-produced by stakeholders at the front end. Third, while other publications focus upon value creation among few stakeholders (Artto et al., 2016; Winter and Szczepanek, 2008), we present a case with a broad coalition of the client, market partners, and knowledge partners.

The research is structured as follows. First, we start with a brief review of the literature on programs and the value creation process. Then, the literature on the front end of programs is discussed, showing the front end as the most significant opportunity for creating value. In the final part of the theoretical section, the concept of co-creation that integrates different actors' knowledge sets is explored. Second, the research method of action research and data collection instruments are discussed. Third, the empirical findings start with a detailed case description of the MWW program, after which three sets of created values are presented. In the discussion section the findings are conceptualized, and finally, conclusions are drawn and attention is given to theoretical contributions and managerial implications.

5.2 Theoretical framework

5.2.1 The subjective nature of values in programs

There has been increasing interest in values in programs, as traditional project management has been criticized for focusing too much on on-time delivery, budget, and satisfying requirements (Winter et al., 2006; Winter and Szczepanek, 2008). Programs have been suggested as value-creating processes

(Winter and Szczepanek, 2008) and are generally understood as "collections of projects having shared goals and objectives and resources all of whose benefits must be realized for the overall program to work" (Morris, 2013: 234). While some scholars notice that the differences between major or megaprojects and programs are difficult to identify (e.g., Morris, 2013), others argue that programs cannot be regarded as scale-ups of projects (Lycett et al., 2004). Programs have broad and fuzzy goals (Artto et al., 2009) that are linked to the strategy of the organization (Pellegrinelli, 1997). In sum, programs are understood as strategic endeavors for creating value.

Although there is little academic definitional agreement (Lepak et al., 2016), value has frequently been defined as a representation of the cost-benefit relationship from an actor's perspective (Laursen and Svejvig, 2016). Value is understood to be subjective and multifaceted (Chang et al., 2013; Larsen, 2015) and can be symbolic (Van Marrewijk, 2017). Martinsuo et al. (2018) distinguished financial, social, regional, ecological and comparative values in their study on the framing of value at the front end of three infrastructure megaprojects. Value is thus negotiated, constructed and created between stakeholders at the front end of programs. To enrich this debate, we turn to the literature on firm-user interaction for product and service value creation (Goel and Yang, 2010; Gosselin and Bauwen, 2006).

Value is created for two sides, the user and the firm (Gupta and Lehmann, 2006), and can include both monetary and nonmonetary and both direct and indirect value (Thiry, 2004). Value-for-firm is perceived as a prerequisite for value-in-use (Goel and Yang, 2010; Gosselin and Bauwen, 2006). The firm-user interaction influences value-in-use in two ways. First, this interaction provides the firm with opportunities to identify, understand and highlight users' needs and points of view (Vargo and Lusch, 2004). The firm can potentially customize its offerings (Payne et al., 2008), which in turn enhances value-in-use for the user (Heinonen et al., 2010). Second, this interaction allows users to potentially maximize their future value-in-use by co-producing products and services together with firms. We see great potential for applying these insights to the front end of infrastructure development programs in which the client and market partners co-create values.

5.2.2. Front end of programs as an opportunity for creating value

The front end has been understood as the most significant stage for opportunities for creating value in programs (Edkins et al., 2013). It is in this phase that the strategic intent of the organization to define specific values in programs is considered. How the front end matters to programs' performance has been widely discussed in the academic literature (e.g. Pellegrinelli, 2002; Rijke et al., 2014; Winter and Szczepanek, 2008). There is a growing academic recognition of uncertainty at the front end of programs (Lehtonen and Martinsuo, 2008; Martinsuo and Lehtonen, 2007), rendering the formulation of programs highly ambiguous (Thiry, 2004). Scholars agree that the lifecycle of programs is neither linear nor predefined and that programs will emerge and evolve (Martinsuo and Kantolahti, 2009). Therefore, Thiry (2004, 2002) asked for the attention for the programs' front end to collectively make sense of the

requirements and needs of programs. Based upon such a front end analysis of the strategy and scope, values that programs intend to deliver are specified (Martinsuo and Lehtonen, 2007). In this way, the front end can create the image of programs (Thiry, 2004). In sum, a good definition of a program's value is regarded as essential for value creation.

Programs have been used as vehicles for infrastructure development contexts (Eweje et al., 2012; Rijke et al., 2014). For example, Rijke et al. (2014) proposed programs to provide the client with more space for dealing with change for developing infrastructures. Front-end activities of defining values and describing how these values can be captured substantially improve the success of program execution. Accordingly, clients tend to involve their contractors in projects and programs as early as possible to have conversations about their goals and intentions before contracts are signed (Matinheikki et al., 2016). This commitment of client organization and contractors to the project's goals forms the basis for their cooperation (Ring and Van de Ven, 1994). Thus, they can come to a better understanding of program details, the allocation of risks and the terms for cooperation. However, Samset and Volden (2016) suggested that both client and market partners have learned little from working at the front end of projects. Therefore, learning capability is required during the front end (Samset and Williams, 2010).

5.2.3. Co-creation and project studies

Co-creation is a management initiative that brings different partners together to jointly produce a mutually valued outcome (Prahalad and Ramaswamy, 2004). With its roots in business studies, co-creation can be defined as "the joint, collaborative, concurrent, peer-like process of producing a new value, both materially and symbolically" (Galvagno and Dalli, 2014; 644). Co-creation thus provides a value creation framework centered on service (Grönroos, 2011; Vargo and Lusch, 2008) in which both firms and users are involved. Mahr et al. (2014) highlighted the importance of integrating different actors' knowledge sets and engaging in mutual explorative and exploitative learning. This is in line with Grönroos and Voima (2013), who insisted on direct, face-to-face contact for co-creation. These developments are in line with Kleinsmann et al.'s (2010) understanding of co-creation as practices in which multidisciplinary participants combine and integrate their knowledge and resources to create value in the design and production stages jointly.

In the past decade, scholars have shown an increasing interest in applying the concept of co-creation at the project level (Eriksson et al., 2017). The concept has been applied to engage different stakeholders, such as client and market partners and other participants, in the process of creating value (e.g., DeFillippi and Roser, 2014; Eriksson et al., 2017; Heredia Rojas et al., 2018; Roser et al., 2013). Co-creation has positive impacts on project performance (Heredia Rojas et al., 2018) and shapes the benefits of sustainable development (Keeys and Huemann, 2017). Co-creation is used to enhance explorative and exploitative learning in the building and infrastructure industry (Eriksson et al., 2017). For example, co-creation has been used by clients hiring engineering firms to jointly learn about the management of

complex projects (Smits and van Marrewijk, 2012). To strategically position itself in niche markets, co-creation can be employed as hybrid models of more than one type of co-creation practice across processes (Roser et al., 2013). However, stakeholder interaction in the program's front end cannot guarantee co-creation when there is a lack of integration between the involved organizations (Artto et al., 2016; Mills and Razmdoost, 2016).

5.3 Research methods

5.3.1 Research design

To understand the contribution of the co-creation sessions in value creation at the front end of the MWW program, we adopted an action research methodology. This research defines action research as an engaged process concerned with the development of practical knowing grounded in a participatory worldview (Kemmis, 2006). Action research aims to empower the client, market partners and knowledge partners in their development of a shared understanding of the MWW program.

The advantages of action research are in the high-quality insights gained from close participation in and engagement with the MWW program. Our research team of four consisted of both practitioners and academics. The third author is a part-time RWS employee and assisted the MWW program manager and organized, together with the Bouwcampus, the co-creation sessions; he actively participated in all sessions. The Bouwcampus is a pre-competitive and neutral space at Delft University of Technology campus where public and private partners in the construction industry can reflect on their collaborative work practices (www.debouwcampus.nl). The fourth author was also actively involved in the MWW program to develop new knowledge of lock standardization. Action research scholars perceive knowledge development as a mutual process dominated by engagement and collaborative relationships (Delhi, 2003). Over time, action research has been established as a set of practices through which researchers identify with the researched and through which research is made contextual (Reason and Bradbury, 2008).

The limitations of action research lie in the risks of the researcher's over-engagement with the field and sympathetic interpretation of research findings (Yanow and Schwartz-Shea, 2015). Furthermore, action research is criticized for not producing high-quality ethnographic data (Reason and Bradbury, 2008), while the building of general theory appears to be difficult, as theory is developed in relation to specific local situations (Delhi, 2003). Finally, encouraging real participation and building relationships with participants, along with acknowledging and sharing power with them, is needed to establish credible accounts.

To overcome these limitations and to safeguard academic standards of scholarship (Gioia and Chittipeddi, 1991), we complemented the researcher team with an outsider researcher, the second author,

who had not been involved earlier in the study. The outsider researcher went through all the reports, interview data and observational notes. In this way, a more objective analysis of the field data needed to publish "good, solid, critical research" (Söderlund and Maylor, 2012; 691) was ensured.

5.3.2 Data collection

The research incorporated multiple methods of data collection, including (1) participant observation, (2) desk research, (3) exploratory interviews with informants, (4) a questionnaire and (5) semi-structured interviews. These methods will be discussed here. (1) Two members of our research team participated in the first stream of the front end of the MWW program, helping to address and collect (inter)national studies on lock designing, and participated in the co-creation sessions in the second stream while one of them, the third author, took on the role of theme group leader. All observations and reflections of the two researchers were noted and worked out. (2) The first author collected the second data source through desk research consisting of the public documents about the MWW program published in Tenderned, the Internet portal that announces new tenders of RWS (www.tenderned.nl), and the Bouwcampus website including the minutes and presentation slides of the sessions, the interim versions and final versions of reports prepared for and produced by the MWW program and the co-creation sessions. In this way, more than 20 detailed reports were collected, half of which were lengthy reports based on a large number of interviews and detailed information about critical events in the MWW program. This information was used to prepare the co-creation sessions and understand the history of the program. (3) Two exploratory interviews were executed by the first author with four informants of RWS to reflect upon the field and the observations. Informants can be very valuable for the understanding and interpretation of research findings (Yanow and Schwartz-Shea, 2015). (4) A questionnaire based upon the preliminary findings was designed and sent to all participants. There were approximately 120 attendees in all co-creation sessions, including representatives at the administrative level from RWS, BNL (the Dutch association of companies in the construction and infrastructure sector) and NLingenieurs (the Dutch association of consulting engineers), and the market level from contractors, engineering firms and knowledge partners. Unfortunately, only 29 respondents accessed the online questionnaire, while only eight were potentially usable. Therefore, we did not use this information for the analysis, only as background information. (5) Based upon all the preliminary findings, a semi-structured interview list was designed and tested with the informants (see **Appendix 5**). Fourteen interviewees were asked to reflect on how they engaged in and what their experiences were with the MWW program co-creation sessions. Interviewees were selected based upon an equal division between employees from client, market and knowledge organizations (see **Table 5.1**). The semi-structured interviews were executed in teams of two researchers to support the researchers' triangulation (Yanow and Schwartz-Shea, 2015). The interviews were conducted in Dutch, with one researcher taking notes that were then transcribed and translated. Semi-structured interviews provide the freedom to explore the ideas and perceptions of the participants in a conversational tone, but also contain fixed topics and predetermined questions that can be compiled to

obtain a certain level of standardization (O'Reilly, 2004). The interpretation of the interviews was checked with the interviewees by email contact.

Table 5.1 Profile of practitioners interviewed

No.	Partner	Years of experience	# of sessions involved	Theme group leader
1	Market	23	3	Yes
2	Market	10	4	Yes
3	Market	29	4	
4	Client	31	4	Yes
5	University	4	4	
6	Market	12	1	
7	Market	36	3	
8	Market	22	4	Yes
9	Client	23	3	
10	University	3	3	
11	University	2	1	
12	Client	41	4	Yes
13	Client	25	4	Yes
14	Client	5	1	

5.3.3 Data analysis

We executed the analysis of the collected data in a three-step process. In the first step of data analysis, the first and second authors read and interpreted text sequences of our data set to assign codes. The perspectives from the insider and outsider researchers were then drawn together to obtain a more in-depth, holistic and enriched view of the co-creation sessions (Yanow and Schwartz-Shea, 2015). Codes were either directly found in the material or constructed from it (Larsson, 2010). Such an analysis, in which data are understood within the context of the case, strengthens claims about actors' interpretations (Yanow, 2005). Four groups of initial codes emerged from this first step: program ambitions, participants' roles, values added, and knowledge developed. In the second step, the literature on programs and value

co-creation were consulted by the first and second author to develop an analytical frame, focusing on value-for-firm and value-in-use, to refine these codes. Inspired by the literature, the sub-codes from the four groups were merged and developed into thematic values with the thematic analysis procedure. As a form of "member-checking" (Yanow, 2005), researchers discussed the thematic codes "awareness of future work opportunities", "understanding of each other's interests", "exchanging knowledge", "complementary to each other", "increased mutual understanding", "continuation of advancing knowledge", "increasing mutual trust" and "reassembling of partners in innovative networks" with several key respondents to verify findings. The final step was the building of theory, which involved a final interpretive process through multiple readings and iterations between tentative assertions and raw data and then drafting successive versions of the text until the present form was determined, which resulted in three sets of value-in-use generated in the co-creation sessions: commercial, intellectual and collaborative values-in-use. These sets will be discussed below, but first, we start by introducing the case and context of the MWW program.

5.4 Findings: commercial, intellectual and collaborative values-in-use

5.4.1. Competing values-for-firm and organizing of co-creation sessions

Ship locks play an indispensable role within the Dutch waterway system networks. The RWS department is responsible for the operation and maintenance of a wide diversity of locks (137), the vast majority of which stems from the early 20th century. Over the next 30 years, 52 of these locks need to be replaced, as some are at the end of their life cycle, while others lack capacity. Therefore, RWS bundled the work, in total worth € 2 to 4 billion, in the MWW program. Typically, each lock is newly designed without standardizing the lock components or considering previous lock design experiences. The MWW program has been designed as a 'learning program' to mobilize expertise from the market and knowledge partners to create resilient locks that are adaptive to future technical, economic and environmental developments.

Central to the MWW program, RWS defined the value of standardization to increase flexibility, adaptation, and quality and to reduce the costs of lock replacement. According to many of the respondents, this value conflicts with the value of freedom of market partners to design and implement innovations in the tender and realization phases of the program: "what we had to check was whether the market was willing to accept our needs for standardization in light of their freedom" (reflection of program manager). This conflict is not exceptional, as public and private partners can have competing values (Klijn and Teisman, 2003). Another ambition of RWS was to implement the new market philosophy of 'the Market-vision,' joint development of the government and the construction sector in the MWW program. This philosophy is based on the values of equality, mutual trust, an open attitude,

and a willingness to cooperate between public and private partners (www.marktvisienu.nl). These values are relatively abstract terms that generally change from more abstract to more concrete notions (Veeneman et al., 2009).

To search for these more concrete notions, RWS organized a co-creation session, which took place for eleven months between April 2016 and March 2017 (see **Table 5.2**). In the first session, an explanation was given of the future perspective and MWW program: "we did have a few ideas but were eager to know if the market had other suggestions" (participant observation April 21, 2016). The participants first brainstormed about the standardization of locks, after which they were divided into five groups, each to reflect upon a specific theme that should be addressed in the standardization of (parts of) locks. Each group distilled the two most important items from all the themes predefined by RWS, resulting in ten themes. During the second session, RWS explicitly asked which of the market partners endorsed the program's philosophy. This hampered the willingness of at least 30% of the attendees from market partners to actively cooperate in the co-creation sessions (participant observation June 29, 2016). The others continued to discuss the themes from the first session and introduced new themes for the program. The third session focused on the enrichment and further development of the themes, resulting in a sixth theme and corresponding group. At the end of this session, each of the six groups presented their themes, on which participants provided comments, improvements, and ideas. Two smaller sessions were organized separately by the theme group leaders, who were responsible for directing the substantive input of the participants. The purpose of these sessions was sharing and enriching the themes within a panel and agreeing on the ambition level result. In the last session, the six groups worked hard on their themes both to share their results and insights with others and to make the themes presentable at the final meeting. Finally, recommendations for the MWW program were made on six lock components that were suitable for standardization. These recommendations were used by RWS to make a better prognosis of the standardization opportunities and the willingness of the market partners to develop them. The results from the co-creation sessions were shared and available to all market partners at Tenderned.

Table 5.2 Co-creation sessions for the MWW program

Session	When	Aim	Description
First session	April 21, 2016	Kick off by RWS and general discussion	RWS as the problem owner, starting the brainstorming on standardization of lock components, with the participants exploring possible themes, distilling the most important themes and jointly providing priorities in themes
Second session	June 29, 2016	Equal, open discussions around selected themes	Discussion over the philosophy of the program. Thirty percent of the attendees quit. Others determining themes from the first session, merging the themes into five themes, dividing

			themselves into five groups
Third session	October 5, 2016	Enrichment of themes	Reducing the social distance between stakeholders. Further elaborating themes, identifying relevant topics for consideration, introducing an extra theme and group
Sub-session	November 8, 2016	Agreeing on the ambition level of the results	Sharing and enriching the themes within the panel, and agreeing on the ambition level result
Sub-session	February 7, 2017	Agreeing on the ambition level of the results	Sharing and enriching the themes within the panel, and agreeing on the ambition level result
Fourth session	March 9, 2017	Common images and recommendations	Making public presentation, receiving feedback, and getting a commitment for six components that were found suitable for standardization

In summary, the competing values-for-firm of standardization and design freedom and the abstract values of equality, trust, open attitude and willingness to cooperate were connected to the front end of the MWW program. By bringing the client, market partners, and knowledge partners together in co-creation sessions (see **Figure 5.1**), these values-for-firm were co-produced into more concrete values-in-use. Based on the interviews and participant observation during the co-creation sessions, we digested three sets of values-in-use: commercial, intellectual and collaborative values (see **Figure 5.2**). These more concrete notions of values are discussed below.

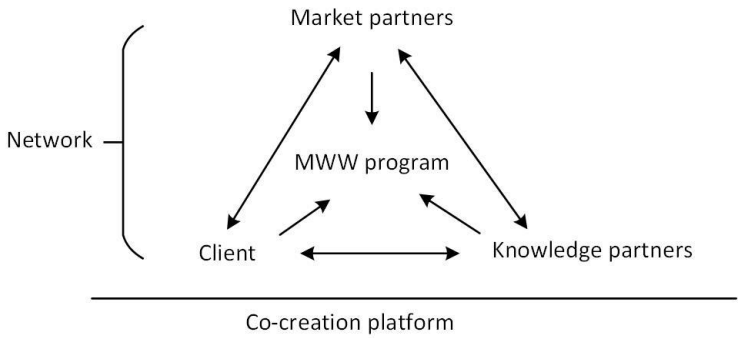

Figure 5.1 Co-creation sessions at the front end of the MWW program

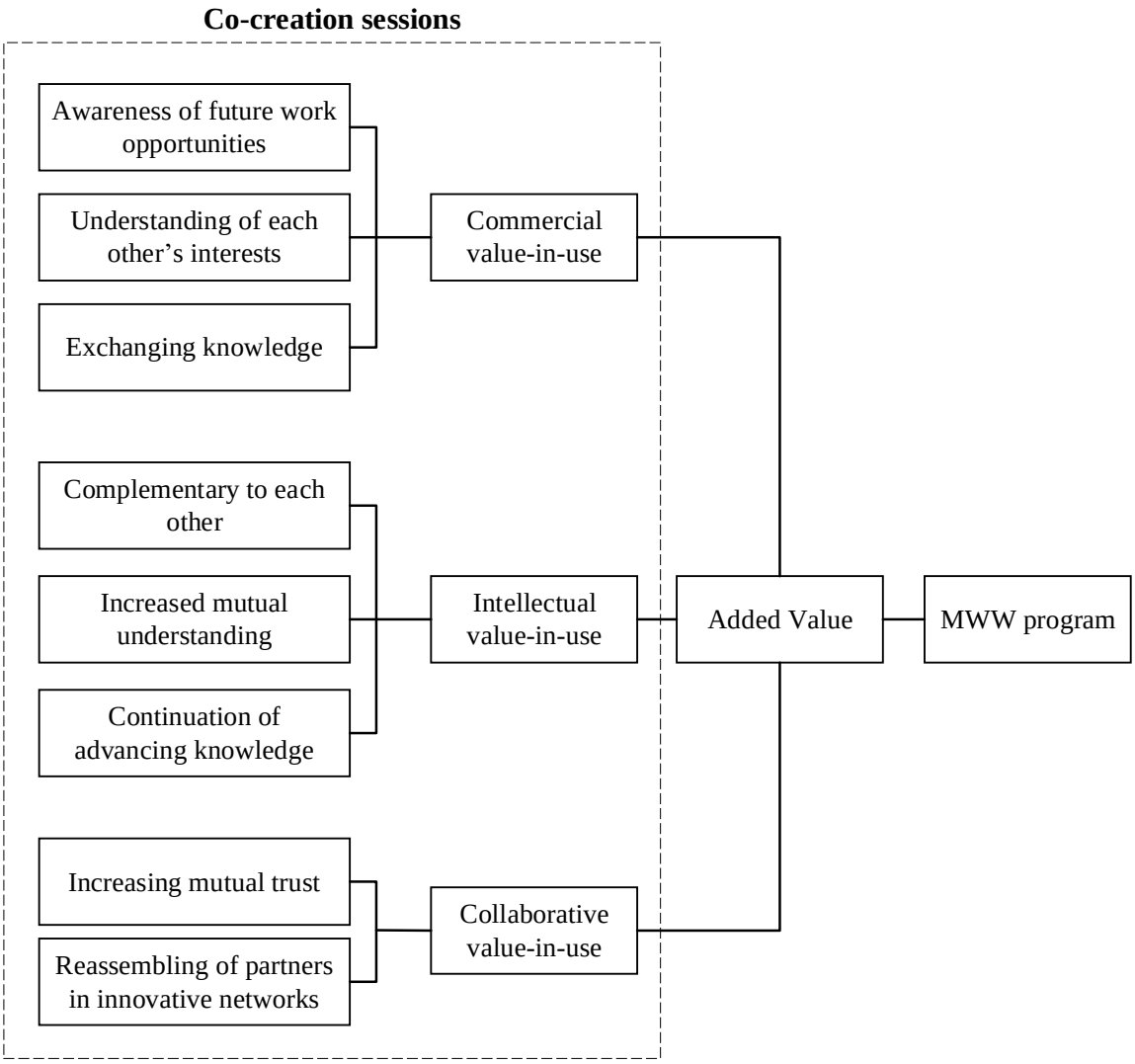

Figure 5.2 Three value-in-use categories and their sub-contents

5.4.2. Commercial value-in-use

Related to commercial value, there is an awareness of future work opportunities, understanding each other's interests, and exchanging knowledge. These three values will be discussed here. First, all interviewees showed a high awareness of future work opportunities of the MWW program. RWS is the largest client on infrastructure development assignments in the Netherlands, and the market partners heavily rely on how it will carry out procurement of the MWW program. During the sessions, it was observed that market partners were interested in "what is in it for me." Client participants did not appreciate this future work orientation. As one interviewee stated,

"They are [only] willing to work together with RWS because they know that there will be something that is worthwhile for their business" (Interviewee 13).

They thought that the market partners came to the co-creation sessions with a double agenda of

collaborating and looking for new work assignments. The same interviewee also said,

"Probably the market is somewhat restless and very keen on getting a contract for a real project" (Interviewee 13).

This attitude of market partners might explain why the first and last co-creation sessions attracted the most attendees; the first sets the scene and the last concluded with a final client decision; therefore, these two sessions are the most important sessions for future work opportunities.

Second, the co-creation sessions also helped stakeholders obtain a better understanding of each other's interests in the MWW program. Given their dependent position, the Dutch government accounts for 90% of infrastructural works in the Netherlands (Priemus, 2004), and market partners are very interested in understanding the client's perspective as RWS decides the direction of how the program will be executed. Through their contribution in developing themes, market partners gained an understanding of the program. As one employee from a market partner stated:

"Most of the time we are falling back into old behavior. You first have to prove your loyalty before the client will think about a more open kind of collaboration. In the end, the contractor is waiting for the client to make the first move" (Interviewee 2).

In addition to the market partners' increased understanding of the client's program, the client gained a better understanding of their partners' interests, opinions and ideas. The co-creation sessions included a much larger audience than in a traditional procurement process, resulting in a larger network. To give one's opinion on the program, interviewees agree that mutual commitment is needed. The interviewees see the many advantages of speaking freely in co-creation sessions, such as *"you definitely need a platform which is absolutely free of judgment" (Interviewee 1)*. However, some interviewees perceived the sessions to be unclear, as themes were still defined and developed by all parties and it is unknown how the program will be continued. The mutual understanding of interests at the front end helps define the goals of the program.

Third, the interviewees mentioned the positive influence of exchanging knowledge as a central value of co-creation sessions. At the front end of an infrastructure development program, the knowledge and solutions developed in previous projects and generated by market partners are very valuable. Ideally, multidisciplinary knowledge is openly shared between the participants to develop the program further. However, this is unrealistic, as knowledge is frequently tacit and valuable to partners. Therefore, participants from both the client and the market partners argued that the exchange of knowledge should be outside of the contract. One of the client employees argues that

"In a project, you are bounded by a contract, and in most of the cases contracts are not open, especially

when tensions increase" (Interviewee 4).

Based on our observations, co-creation sessions provide a "cheap place" for collecting, validating and verifying information from both the client and the market partners.

"I think it is not about gaining. It is about exchanging information and knowledge" (Interviewee 10).

This open environment was welcomed as *"asks for active participation" (interviewee 7)* and *"forces the participants to have open communication" (Interviewee 5)*.

5.4.3. Intellectual value-in-use

Based on our study of the co-creation sessions, we digested three intellectual values-in-use. First, interviewees acknowledged and we observed during the sessions that market partners and the client can be complementary to each other, as they require valuable but different knowledge: client experience, market experience, and scientific research. The client wants to make more effective use of the expertise, knowledge, and potential innovation of the market:

"It was nice to see that a lot of people with different professions, different knowledge, and different positions within their organization were gathered in one room, and most of the time there was one discussion (item)" (Interviewee 10).

Interviewees were enthusiastic about the diverse and sometimes conflicting understandings of program themes. For example, in the second session, we observed an active phase in which inspirations were obtained from participants' perspectives on sustainability. In contrast to the market partners, the client understood sustainability as a precondition and clear ambition for all the themes in the MWW program. Conflicts over program themes can stimulate discussion and creativity, which can ultimately result in the client engaging in a better decision-making process. Complementary knowledge can develop program themes that satisfy evolving local demands and lead to new work practices in the program. In this way, co-creation sessions developed smart ideas and concepts for a better definition of the MWW program.

Second, we have observed how the sessions increased mutual understanding among the participants involved. Interviewees claimed that

"By performing co-creation, a better understanding of each other's interest has been achieved, which encouraged a further collaboration even more" (Interviewee 3).

Frequently, the term 'looking in each other's kitchen' was mentioned, indicating that it was good to understand each other's interests, work practices, and cultures:

"It is all about the process: understanding used methodologies, knowing the context, learning about the language of the other" (Interviewee 1).

For example, exploring how market partners understand standardization can be useful for the lock owner, lock designer and lock builder. Learning from these experiences leads to a better understanding of the possibilities and processes of standardization. The challenge of the co-creation is that most submissions are not very useful, not practical and difficult to implement. Some comments from the market partners argued that a shared understanding is needed:

"The sessions provide the ability to empathize and to discuss freely possible solutions. So in the end, we all have a better understanding of the clients' problem" (Interviewee 2).

The participants emphasized co-creating capabilities that will integrate interdisciplinary knowledge and research, treating stakeholders as the source of knowledge for finding problems and solving problems, emphasizing the completion of design work together in cooperation and negotiation.

The co-creation sessions were limited to guaranteeing the continuation of advancing knowledge. The pre-competitive trajectory is a good start to challenge the market partners to develop the new and innovative knowledge needed to execute the MWW program. The experiences gained and knowledge developed in the co-creation session could be a starting point for future knowledge development by the market partners, especially when the results of the co-creation sessions are made public. However, to market partners, knowledge continuity is a substantive contribution, as it is frequently expensive and tricky and in the long term, it is unclear whether it is necessary. Participants worried about the continuation of knowledge sharing. One interviewee stated that

"It is not continuity of knowledge, but the continuity of sharing information that is important" (Interviewee 13).

Some suggested that to keep knowledge sustainable over time, regular co-creation sessions should be organized by the client with the market partners. Participants can then continue to learn from each other and opportunities for creating a larger shared market can be explored. This maximizes the possibility of learning and ensures continuity, as one market partner advised *"to organize this knowledge on disciplines instead of generating ideas in the future. Make it more concrete and applicable in real projects" (Interviewee 6)*.

5.4.4. Collaborative value-in-use

Apart from commercial and intellectual values, we found two collaborative values related to the co-creation sessions: increasing mutual trust and reassembling of partners in innovative networks. First, interviewees claimed increasing mutual trust between RWS and market partners during the execution of

the co-creation sessions. A market partner stated that

"At the start, we as contractors are looking for "what's in it for us," but during the later sessions, my concerns disappeared more or less, and I was more open and was eager to give my own opinion" (Interviewee 8).

From the first session, cooperation was put on the agenda. In subsequent sessions, personal interests and ambitions were discussed. As one of the interviewees stated,

"Market [partners] were somewhat laid back. At first, they were only interested in selling knowledge that they thought was safe to share. This was personalized, as some persons were more open than others. In the end, the atmosphere was more open because participants were better acquainted with each other" (Interviewee 3).

We observed the growth of mutual trust during the co-creation sessions in which various stakeholders worked together with a clear shared vision of interest. This is important, as earlier studies (e.g., Van Marrewijk et al., 2014) show that public and private actors find it difficult to experiment with innovative collaborative behavior encapsulated in power relations. Mutual trust between public clients and market partners was an important and sensitive topic in the Dutch construction sector after a parliamentary inquiry into construction industry malpractice in 2002, and both clients and market partners were forced to afford greater transparency and accountability (Sminia, 2011; Van Marrewijk et al., 2014). When these co-creation sessions are experienced by participants to contribute to improved collaboration, this is an important outcome.

Second, reassembling partners in innovative networks was an essential value-in-use of the co-creation sessions. Several interviewees expanded their relationship beyond the MWW program to other projects:

"Co-creation will lead to a sort of personalized friendship which is needed to start a further collaboration between client and market. The real collaboration starts after the co-creation" (Interviewee 4).

The co-creation platform itself produces very little content, but according to interviewees, a large number of the participants become the leading producers of content. The core of the platform is to guide and promote user participation. According to one participant from a market partner,

"In a way, it is efficient, having all parties together and talking and listening and in that way learning from each other" (Interviewee 6).

In the interviews, it became clear that the mastery of professional knowledge is no longer the only requirement for the market partners. Given the societal impact of infrastructure development projects

(van den Ende and van Marrewijk, 2019), market partners must manage, coordinate and communicate with project stakeholders, transferring attention from production to management and integrating networks of stakeholders.

5.5 Discussion

This research investigates what stakeholders do in co-creation sessions and how this contributes or limits the co-creation of value at the front end of the MWW program. The findings of our action research study show that by redefining the replacement of ship locks as a program instead of a collection of stand-alone projects, the client announced their ambition to connect the value of standardization and the intention to implement abstract notions of values on public-private collaboration to the program. In contrast to these ambitions, the market partners highly valued their freedom to design and implement innovations in the tender and realization phase of programs. The co-creation sessions brought together client, market partners, and knowledge partners to reflect upon these competing values-for-firm (Grönroos, 2011) and created an open space for discussing the market partners' and client's requirements regarding standardization. These discussions resulted in three sets of values-in-use (Goel and Yang, 2010): commercial, intellectual and collaborative values.

5.5.1 Front end co-creation of values-in-use

The findings of the study have shown, as was suggested in the literature (Edkins et al., 2013; Thiry, 2002), that the co-creation sessions at the front end of the MWW program provided two excellent opportunities for defining and creating values for the stakeholders. First, it was an opportunity for stakeholders to discuss their competing values-for-firm of standardization (RWS) and freedom (market partners). Competing values are no exception, but characteristic of public-private collaboration in the construction sector (Van Gestel et al., 2008), as the values of public and private partners can be different (Klijn and Teisman, 2003). In the co-creation sessions, commercial and intellectual values-in-use were negotiated. Second, it was an opportunity to discuss the client's ambition of implementing abstract values of equality, trust, and openness in the program. In the co-creation sessions, the value-in-use of "increasing mutual trust" and "reassembling partners in innovative networks" emerged. The co-creation sessions at the front end thus helped mobilize the stakeholders to create the right values-in-use for executing the MWW program. These findings are in line with Winter and Szczepanek (2008; 96), who state that "the general task of a project or program is not to create value for customers but to mobilize customers to create their value from the project or program's various offerings."

The MWW program study shows that the concepts of value-for-firm and value-in-use, originally conceptualized in business and service literature (Goel and Yang, 2010; Gosselin and Bauwen, 2006), are useful for studying value creation in programs. Public and private stakeholders have different interests and viewpoints that must be integrated (Bowman and Ambrosini, 2000). As the concept of

value is subjective (Chang et al., 2013), the co-creation of values-in-use can be understood as a way to negotiate values-for-firm in complex and uncertain project contexts, as has been requested by Martinsuo et al. (2018). The client announces the program's ambitions while market partners are attempting to maximize future value-in-use, for example, for qualifying for new work opportunities. Co-creation sessions customize values-for-firms at the front end of programs into value-in-use, for example, in defining six possible lock components for standardization. In this way, the concepts of value-for-firm and value-in-use help understand the dynamic interaction between stakeholders at the front end of programs.

5.5.2 Contributions and limitations of co-creation

The MWW program study has found three contributions of co-creation sessions for creating value at the front end. First, co-creation sessions help client and market partners to communicate about and improve value propositions before they are bound by a formal contract. Central to these sessions is knowledge exchange, discussions of earlier experiences with similar projects, and open discussion between stakeholders that can identify adaptive solutions and supplement and strengthen the value propositions addressed to programs. As has been suggested by others (Martinsuo and Killen, 2014), co-creation sessions play an essential role in governing the program and specifying the program value strategically. Notable here is that stakeholders, in our case, the market partners, client, and knowledge partners, acknowledge that no type of knowledge is superior to another (Edelenbos et al., 2011). This is not easy as equal power distribution among stakeholders is in contrast to the hierarchical, centralized infrastructure sector (Van De Meene and Brown, 2009). Second, co-creation sessions reduce the social distance of stakeholders at the front end of programs. All participants are given an equal opportunity to pitch their perspectives on programs and are invited to discuss what they expect from other participants. Third, and related to the two above-mentioned contributions, is that the co-creation sessions stimulate the emergence of a multidirectional interactive network of suppliers, engineer firms and knowledge partners. This network empowers stakeholders to interact and stimulates their equal and active participation, something that is not common in the infrastructure sector (van Marrewijk et al., 2008). Therefore, co-creation is very helpful for improving public-private partnerships in the infrastructure sector since there is an urgent need to answer the societal question of climate change, energy transition, and mobility (Sminia, 2011; van Marrewijk et al., 2008).

The MWW program study also shows two limitations of the front-end use of co-creation. The first is related to the power imbalance between client and market partners. The initiating client can easily take over other voices with their dominant voice (Sminia, 2011), while it is entirely free to use the outcomes of the sessions. Second, while co-creation needs broad participation of all stakeholders, 30% of the stakeholders withdrew from the MWW program, as they did not want to give away their knowledge and design solutions for locks. Only those participants who saw future work opportunities were willing to

share their knowledge. Second, co-creation sessions need the substantive contribution of partners to prevent a "ritual gathering". The MWW program client collected six possible lock components for standardization, but expected (much) more, as it hoped to create a catalog with components and bring it to the market.

5.5.3 Value creation in programs

The study shows the potential of programs over projects for creating values when a collection of stand-alone projects (locks) is redefined into a program (MWW). Programs are more efficient than separate projects placed on the strategic agenda of organizations and thus guarantee longitudinal managerial attention and direction (Martinsuo and Killen, 2014). Strong project-based cooperation between the client and their market partners, with often varying combinations of teams, stimulates stakeholder engagement and partnering. Partnering arrangements might serve as engagement platforms that enable the client and market partners to co-create value on infrastructure development programs (Jacobsson and Roth, 2014). Therefore, we argue that values are better secured within a program than in a collection of stand-alone projects.

Important for the creation of value in programs is the organization of the follow-up process. If it is not clear how the process is organized and what partners will do with the newly gained knowledge and relationships, the continuation of programs will be under pressure (Näsholm and Blomquist, 2015). In the MWW program, there was a lack of clear feedback on the continued program and follow-ups to keep the network alive. Co-creation sessions can be further developed into a kind of Community of Practice platform (Mutch, 2003) with an explicit agenda. In such a community, long-term relationships can be developed, while learning and discussing new practices continues (Bjørkeng et al., 2009). This is in line with the business value provided by a Community of Practice (Mihladiz et al., 2011). Samset and Volden (2016) suggested that both client and market partners have not learned many lessons about how to work at the front end of projects. Previous research (Sminia, 2011; Van Marrewijk et al., 2014) has shown that current practices of collaboration between public and private parties in the infrastructure need improvement. A collaborative learning community seems to be an interesting opportunity to improve this collaboration and make learning a long-term goal.

5.6 Conclusion

Our research makes three contributions to value creation in the program literature. First, it adds an in-depth case study of stakeholders who co-create values-in-use at the front end of a program. This answers the call by Smyth et al. (2018), Martinsuo and Hoverfält (2018) and Martinsuo et al. (2018), as few empirical studies have been executed on value creation at the front end of programs. Understanding how co-creation is applied in programs increases our understanding of co-creation application in a multi-stakeholder setting apart from the production stage of construction projects (Eriksson et al., 2017).

Second, we used literature on firm-user interaction for product value creation (Goel and Yang, 2010; Gosselin and Bauwen, 2006) to theorize the co-creation process in programs. The co-creation of values-in-use can be understood as a way to negotiate values-for-firm in complex and uncertain project contexts, as has been requested by Martinsuo et al. (2018). We have identified three sets of value-in-use co-produced by stakeholders at the front end. Thirdly, while other publications focus on value creation among a few stakeholders (Artto et al., 2016; Winter and Szczepanek, 2008), we show that co-creation sessions with a broad coalition of the client, market partners, and knowledge partners must be well organized to create values-in-use at the front end of programs.

The research has empirical implications for both client and market partners as value co-producers in infrastructure development programs. Although the concept of co-creation is not widely known in the infrastructure sector (Edkins et al., 2013; Thiry, 2002), it provides an opportunity for a balanced and enriched realization of value among stakeholders in programs. The front end of program interaction is essential to understand the client's value-for-firm. It is also an exciting intervention in current practices of collaboration between public and private partners in the infrastructure sector, as working in co-creation requires a mind shift by stakeholder employees (Jacobsson and Roth, 2014). Well-organized co-creation sessions can thus be helpful to implement sector strategies such as Market Vision. Therefore, a clear long-term platform is needed to make the interaction of stakeholders possible (Lee et al., 2012). Hopefully, this may stimulate further, more widespread use of co-creation in the infrastructure sector.

The study has several limitations and recommendations for future research. First, the single case study limits the application of the findings to other sectors and nations. Follow-up research could explore the co-creation of values-in-use in other infrastructure development programs or mega projects that have been managed as programs (Hu et al., 2016). Moreover, the choice of action research and the decision to interview only involved stakeholders may limit critical reflection (Yanow and Schwartz-Shea, 2015). From a methodological perspective, long-term value capturing should be investigated in the execution stages and post-project reviews. Since the on-going case of the MWW program focuses on the value creation and capture of co-creation sessions at the front end, future longitudinal research is needed to include more data in the execution stages and post-project reviews to extend our findings.

Appendix 5 Interview protocol

Q1 Which co-creation sessions of the MWW program did you attend?

Q2 In which stakeholder do you work, and what is your role?

Q3 What is a program according to you?

Q4 Which opportunities do you foresee?

Q5 Were the participants equal in their roles during the co-creation sessions?

Q6 What is the exact contribution of co-creation to the process of value creation?

Q7 How does this process look like, how is it working?

Q8 What is needed next to perpetuate the knowledge gained?

Q9 What would you like to see in the future?

Q10 How will this result in better collaboration and what should the process look like?

Q12 Do you agree following statements? (Strongly disagree, disagree, neutral, agree, and strongly agree)

- Co-creation sessions can provide an open place for collecting reusable information from the client and the market.
- Co-creation sessions can be seen as a program (MWW) start-up meeting.
- Co-creation sessions have produced an open setting, why, how.
- The sessions were necessary to open future opportunities.
- Co-creation is an efficient way to store and share newly gained knowledge between the client and the market.
- The market and client can complement each other's knowledge with different perspectives.
- Co-creation sessions can strengthen the shared understanding between the client and the market. How will this work out throughout co-creation?
- The results of the co-creation sessions published on the Bouwcampus and Tenderned website ensures the knowledge continuity. How are you going to use this newly gained knowledge? What is needed next for continuation?
- Co-creation sessions can foster knowledge sharing and promote mutual trust.
- Equal participant role setting can result in an increase in partnerships between public and private actors.
- Different participants can form a value network rather than a pipeline within the co-creation sessions.

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Chapter 6 Collaborate to Learn and Learn to Collaborate: a Case of Exploitative Learning in the Inter-organizational Project

Abstract

Management of inter-organizational projects focuses on the collective benefits of a group of organizations on a shared activity for a limited period and coordination. However, how learning is facilitated in the inter-organizational project remains under-developed in the literature. This research analyses the exploitative learning process in the longest tunnel project on land in the Netherlands realized in a densely populated area. Data were collected through archived documents, in-depth interviews, and site visits in the ethnographic research to analyze the actors, the daily practices, and social situations in projects. The empirical findings indicate that exploitative learning is promoted positively between the owner and the contractor and internally within the contractor. The most significant change that the exploitative learning process has led to is the change in mindset towards collaboration. Project culture is considered to be shaped by exploitative learning in the inter-organizational project. However, there is a gap between the transfer of knowledge from the inter-organizational project to the parent organizations. The findings have implications for understanding learning in the inter-organizational project setting.

Keywords: Inter-organizational project, project culture, exploitative learning, mindset change, collaboration

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6.1 Introduction

As more and more infrastructure development projects are being built and maintained, the need to manage projects effectively and efficiently requires learning from its internal and external experiences, to draw on lessons learned to avoid making the same mistakes, and ultimately to achieve better delivery. To satisfy the requirement, project teams usually rely on previous knowledge and experience for creating solutions (Brady and Davies, 2004). The prospect of capturing the learning from project-based work and making it available within and across projects and to the broader organization as 'best practice' is particularly attractive (Kerzner, 2018). There has been growing academic interest in exploratory and exploitative learning in the infrastructure project management practice (Liu and Leitner, 2012; Petro et al., 2019; Worsnop et al., 2016).

The infrastructure development industry is known to be a mainly locally organized and conservative sector with a myriad of actors (Kisi et al., 2016). The nature of large projects separates people from different parties. They are eager to collaborate, but except for the necessary handover required by the contract, they have trouble identifying to extract value from those collaborations. Knowledge is often lost after the completion of a project because project team members move on to new projects or occasionally go back to their line functions (Schindler and Eppler, 2003). In practice, infrastructure development projects' decentralized and discontinuous nature leads to broken learning and feedback loops (Gann and Salter, 2000). The construction industry is often criticized for slow learning or not learning at all (Flyvbjerg et al., 2002; Hertogh et al., 2008). Learning seems to take place often quite intensively at the project initiation (Fangel, 1991) and the end of the construction phase (Rezania and Lingham, 2009). Most learning experiences occur more or less accidentally on the job, and support for learning from these experiences is limited (Savelsbergh et al., 2016). Therefore, it calls for more research on how learning can be better exploited in the collaborative environment of inter-organizational infrastructure development projects.

The research was performed on the design and construction of the Gaasperdammer Tunnel (GSP) project in Amsterdam, the Netherlands. There has been a learning trajectory program set up by Rijkswaterstaat (RWS), the executive body of the Dutch Ministry of Infrastructure and Water Management, in collaboration with IXAS, the winning consortium of contractors (mentioned as the contractor in this article), which was organized to have a constant reflection during the project rather than just learn from the post-project report.

The research will focus on viewing the relationship between the multiple organizations in a project from a learning perspective. The actors' experiences from both owners and contractors will be investigated and analyzed in the inter-organizational project setting. We have the following research question: What are the effects of exploitative learning carried out by the inter-organizational project actors?

We will seek to understand the potential convergence between "collaborate to learn" and "learn to collaborate" to establish a link between learning and collaboration. Since all parties have their own culture and ways of working, we have to invest the time to learn to collaborate with all the parties, and when collaborating, we continue to learn from each other.

The research is structured as follows. First, we start with a brief review of the literature on organizational learning and exploitative learning in the inter-organizational project, showing that exploitative learning in the inter-organizational project setting needs to be better explored. Second, a detailed case description of the exploitative learning process within the GSP project is presented. The research method of data collection and analysis is provided. Third, the empirical results are given, following the conceptualized findings and discussion. Finally, conclusions are drawn, and attention is given to theoretical contributions and managerial implications.

6.2 Literature review

6.2.1 Inter-organizational project

Often conceptualized as a temporary organization, large infrastructure projects are established within and between organizational functions and span organizational boundaries, categorized regarding intra-organizational and inter-organizational nature (Burke and Morley, 2016). In practice, these projects are set up so that multiple organizations work jointly to produce goods and services in a limited amount of time, and multiple knowledge flows coincide (Jones and Lichtenstein, 2008).

An inter-organizational project can be understood as an association of diversely skilled employees from several organizations who temporarily interact to coordinate their efforts to accomplish a complex task (Bakker, 2010; Levering et al., 2013; Sydow and Staber, 2002). Lundin and Söderholm (1995), Sydow and Braun (2018) summarized the characteristics of inter-organizational projects.

- The inter-organizational project can serve as a bridge between multiple levels (within and across projects). Relationships between organizations may be latent after the project ends until they are activated in future projects.

- The inter-organizational project can influence the organization’s bureaucracy through inter-organizational teams. Each organization has its hierarchy and routines. When organizational boundaries intersect, organizations need to define the roles of people in the inter-organizational project to work simultaneously on different levels.

- The inter-organizational project can blur organizational boundaries. When members of different organizations are assigned to a project, they work together to complete a given task. It asks for a dynamic perspective to ensure the commitment of project team members from different

organizations.

- The inter-organizational project can re-construct the behavior of project team members. To accomplish the task, members of different organizations need to have inter-organizational governance, enabling the inter-organizational project members to behave consistently with their organizations and with the inter-organizational project.

Previous literature on inter-organizational relationships in the project explored several theoretical lenses such as strong owner (Winch and Leiringer, 2016), systems integration (Davies et al., 2009), meta-organizations (Davies and Mackenzie, 2014), project-based networks (Manning, 2017; Pryke et al., 2018), and project network organizations (Lundin et al., 2015).

Construction projects are a typical inter-organizational example (Burke and Morley, 2016). The implementation of an infrastructure development project often involves multiple parties, such as owners, designers, contractors, subcontractors, and suppliers, who establish or maintain partnerships through one or more discrete projects. Project team members are deployed from the participant organizations and cooperate in the construction process. At the same time, it is necessary to ensure that the project's results align with their respective organizations' development strategies. The knowledge created within inter-organizational projects is likely to dissipate when the project comes to an end, and the participating organizations separate (Bakker et al., 2011a).

6.2.2 Organizational learning in projects

Organizational learning has great potential for influencing organizational outcomes (Levinthal and March, 1993) and is the primary determinant of performance differences among firms (Crossan and Berdrow, 2003). Learning becomes crucial when the project is inter-organizational, having multiple organizational stakeholders. The emergence of inter-organizational structures would contribute to information sharing and collective meaning (DiMaggio and Powell, 1983).

Scarbrough et al. (2004) defined project-based learning by conceptualizing both the creation and acquisition of knowledge within projects and the consequential transfer of this knowledge to the broader organization and other projects. Bartsch et al. (2013) defined learning in project-based organizations as the process of integrating project knowledge, recognizing many learning opportunities in the projects they conduct with other partners. Learning in the inter-organizational project represents a specific type of organizational learning. Because of involvement of multiple organizations, this type of learning can be characterized as being multiparty and inter-organizational (Holmqvist, 2003).

Project-based learning, which is mainly ad hoc, requires commitment and continuous investment of time and resources, yet it is often neglected (Davies and Brady, 2000; T. Williams, 2008). Inter-organizational project-based learning seldom occurs in the traditional short-term competitive relationship. The

frameworks and models of learning developed for permanent organizations (Duffield and Whitty, 2014) may not apply to temporary construction organizations. Moreover, the learning mechanisms often are discussed in an intra-organizational instead of an inter-organizational context, thus focusing on how a single organization learns across projects (Prencipe and Tell, 2001). Learning in inter-organizational projects can be more difficult because of the involvement of multiple organizations with incongruent goals, overlapping areas of responsibility, and unequal expertise levels (Jones and Lichtenstein, 2008). Cross-functional or cross-organizational resources make it challenging to execute projects within the traditional organizational boundaries, which complicates the transfer and reuse of useful lessons. Further research is needed to address this gap in extant literature.

6.2.3 Exploitative learning in projects

Learning in organizations is often categorized into two main learning modes: exploration and exploitation (March, 1991). Mahr et al. (2014) highlighted the importance of integrating different actors' knowledge sets and engaging in mutual explorative and exploitative learning. Exploitation involves activities characterized by refinement, efficiency, and execution, whereas exploration involves activities characterized by search, discovery, experimentation, and innovation (He and Wong, 2004; March, 1991). The tension between exploration and exploitation on the firm-level has been mostly studied in earlier research (O"Reilly and Tushman, 2011; Uotila et al., 2009). It became necessary to figure out how exploration and exploitation can be facilitated in inter-organizational relationships in different organizational contexts (Im and Rai, 2008), for example, in project settings. More research is needed to study how exploration and exploitation are managed at the project level (Turner et al., 2015).

Exploitation is associated with routinization, incremental development, and short-term orientation (Andriopoulos and Lewis, 2010; Junni et al., 2013). It has been studied at the firm level by prior research (Swift, 2016; Uotila et al., 2009). In the project organizing context, exploitative learning focuses on controlling existing knowledge and addressing customers' needs to achieve high levels of consistency and efficiency (Zerjav et al., 2018), which is much needed in traditional construction projects. Eriksson et al. (2017) further identified knowledge sharing and innovation diffusion as key exploitative learning themes.

The fragmented nature of the construction market makes incremental innovation more commonly adopted. Construction projects benefit from exploitative inter-project learning to achieve efficient use of limited project resources (Eriksson and Leiringer, 2015). However, construction projects often do not well record early recollections. They are less likely to spend time and effort articulating knowledge and capturing lessons learned (Perminova et al., 2008) under the pressure of finishing projects before the ex-ante defined deadline. The owner may use an external audit to evaluate the project delivery. However, often audits aim more to judge than to learn, looking back at what happened in the past instead of looking forward to approaching future issues. The evaluation is only a snapshot at the end of the project.

Exploitative learning could help project teams avoid repeating the same mistakes (Brady and Davies, 2004) and refine existing ways of doing things while avoiding experimentation risks (Shaw, 2017). More attention should be paid to the exploitation during implementation rather than at the end of the project.

6.3 Research Methods

6.3.1 Ethnographic research

Answering the research question will be done through ethnographic research. Initially developed in social anthropology to observe radically varied cultures, ethnography is developed as a qualitative method for collecting rich and complex social data (Fine et al., 2009). It allows various fieldwork methods to study organizations, cultures, daily practices, and groups of actors (Schwandt, 1996). The combination of the fieldwork methods entails participant observation, interviews, and the close reading of documents or other sources (Sierk et al., 2009). The contribution of ethnographic studies is evidenced by the small but growing number of scholars using ethnography as a methodological approach in studying construction projects (Phelps and Horman, 2010; van Marrewijk et al., 2016).

6.3.2 Case description

The Netherlands is an appropriate research setting for cultural reasons, for its ubiquitous consensus-seeking mentality. The Dutch polder model culture fosters close collaboration among participants (Papadonikolaki et al., 2019). In the Dutch construction industry, most projects are carried out by many different organizations, and the contractor, in most cases, is operating in the form of a consortium. That means that learning often takes place in an environment where more than one organization collaborates. It is an environment that is more likely to be more collaborative and could be better suited to study learning in inter-organizational projects (Bakker et al., 2011b).

The case selected is the Gaasperdammer tunnel (GSP) project, a land tunnel between the Amsterdam-Utrecht railway line and the Gaasp River in a densely populated area, part of the road extension between Holendrecht and Diemen, and belonging to the largest infrastructure program in the Netherlands, the SAA program (Schiphol-Amsterdam-Almere). The tunnel is three-kilometer long with a park on top that connects the neighborhoods in Amsterdam Southeast on both sides of the tunnel. The project was started in August 2015 and is planned to be delivered in October 2020. Then it will be the longest tunnel on land in the Netherlands. The owner RWS has set up an integrated project management team to manage the GSP project. Three separate organizations, Fluor, Ballast Nedam, and Heijmans, joined together and formed IXAS, the contractor consortium, to complete the GSP project in a DBFM (Design, Build, Finance and Maintain) contract.

In 2015, the Sluiskil Tunnel project, which has budget underrun and was completed in time, was evaluated in collaboration with COB (the Center for Building Underground, Centrum Ondergronds

Bouwen in Dutch). This network organization focuses on gathering, developing, and unlocking the knowledge of underground construction. The results appeared in a book (Hertogh et al., 2015) and were shared via a conference with the sector at the tunnel opening. This evaluation inspired the GSP project directors to consider their own project critically. They went a step further than the Sluiskil Tunnel: they started a knowledge project, together with the client RWS and contractor IXAS facilitated by COB, from the beginning so that fresh experiences are immediately collected and shared, which is later called the "learning trajectory program." The ambition was to add extra value by starting well before the contract was agreed. This process will promote efficient knowledge usage and elicit improved learning and problem-solving skills in the project environment itself, which we defined as exploitative learning. There was already the provision for this in the contract: regular alignment sessions in which the client and contractor exchanged views on specific topics. There is also a clear incentive to improve knowledge sharing between the different parties. A plan of action was drawn up for the exploitative learning process in 2016 at the outset. RWS and IXAS have documented lessons and experiences gained in the GSP project in collaboration with COB. At this moment, it is the biggest learning trajectory program in the Dutch construction industry. The entire exploitative learning process and cooperation will continue up to the completion and delivery of the tunnel. The setup and experiences of the first phase (2014-2016) and the second phase (2016-2018) covered knowledge meetings, two books in print (Hertogh, 2019, 2017), and knowledge sharing on the website. One of the recommendations was to evaluate the learning: to learn from learning.

We selected the case based upon the criteria of the project's size with inter-organizational relationships, the focus on the exploitative learning during the execution phase, and the depth in the project we participated in. We carried out ethnographic research to analyze how the parties involved in the GSP project have learned from the ongoing process. The engaged scholarship facilitates in gaining an in-depth understanding of organizational complexity (van den Ende and van Marrewijk, 2019), i.e., exploitative learning in an inter-organizational setting in this case, which also aims at knowledge co-creation between academics and practitioners (Liu et al., 2019; van Marrewijk and Dessing, 2019).

6.3.3 Data collection

The data were collected through document analysis by the first author, the ethnographic research from February to July 2018 by the first and second author, onsite participant observations by the third author since the start of the project (activities see **Appendix 6.A Table 6.2**), and interviews by all authors (protocol see **Appendix 6.B**). The second author acted as an intern for half a year to help the project parties to improve their exploitative learning. The third author combined the roles of ethnographer and consultant. The first, fourth, and fifth authors went through all the reports, interview data, and observational notes. Various methods, such as site observations and validation interviews, helped to triangulate the empirical findings to overcome the limitation of the sympathetic interpretation of

research findings (Yanow and Schwartz-Shea, 2015). The triangulation of methods allowed a reliable and valid view of how the members of both IXAS and RWS experienced the learning trajectory program and whether they experienced changes due to the learning trajectory program.

The books mentioned above about the GSP project gave general insight into how the exploitative learning process has been intended and how it has been put into place in the project. The RWS and IXAS project team members interviewed were all involved in the making of the COB books. Thirteen semi-structured face-to-face interviews were conducted, among whom five come from RWS, six from IXAS, and two from COB; five have a technical background, and eight have a managerial background (see **Table 6.1**). The interviews varied in duration but ranged between 60 and 90 minutes. Additional data were sourced from attending weekly meetings held in the GSP project in Amsterdam, the construction site visit, and having multiple informal conversations with onsite project managers.

Table 6.2 Interviewee profile

No.	Role	Organization	Gender
1	Environmental Manager	RWS	Male
2	Former Environmental Manager	IXAS	Female
3	Maintenance Engineer	IXAS	Male
4	Head of Communications	IXAS	Female
5	Tunnel Technical Installation Manager	RWS	Male
6	Tunnel Technical Installation Manager	IXAS	Male
7	Contract Manager	RWS	Female
8	Director of IXAS	IXAS	Male
9	Project Manager	IXAS	Male
10	Project Manager	RWS	Male
11	Project Manager	RWS	Male
12	Consultant	COB	Female
13	Consultant	COB	Male

6.3.4 Data analysis

Semi-structured interviews were all recorded with the permission of the interviewees. These recordings were transcribed and translated from Dutch to English and given codes by the first and second author.

The transcript was thoroughly read and analyzed and classified into codes by all authors as insider and outsider researchers. Themes that came across in the transcripts, informal talks, participant observations, and COB books were therefore interlinked. Inside and outside perspectives contribute to a more holistic and objective view of exploitative learning in the inter-organizational setting (Yanow and Schwartz-Shea, 2015).

Our unit of analysis is project actors' inter-organizational actions and interactions in the exploitative learning process. The attention might shift towards the way people make sense of what happened and not so much to what happened actually. Only the fully agreed practices were finally retained.

There was a significant overlap between data collection and data analysis, and they influenced each other. Critical practices and phenomena were identified, relying on labels representing similar descriptions across multiple data sources. We devoted subsequent literature readings to assembling these concepts into categories that defined similar ideas, issues, or relationships relevant to the informants. We developed an analytical frame, focusing on two dimensions to refine the codes: the exploitative learning process and inter-organizational relationships. We moved back and forth between the case and the concepts, tentative assertions, and raw data. In this way, we built the theory, which will be discussed below.

6.4 Results

6.4.1 Overview of the exploitative learning process

6.4.1.1 Learning as a management tool

A learning project organization does not arise automatically and requires attention and belief in the added value. Project managers from RWS hoped to experience the exploitative learning process as an extra management tool. They highlighted that by stating, "*without the prescriptions, my team members would have the excuse of doing nothing* (Interviewee 2)." They emphasized how the exploitative learning process has helped them to improve their daily work. The goal of capturing and sharing knowledge also appeared in other interviews as expected. Project managers from IXAS recalled this in many ways:

"We did not have any contractual obligation to learn in the past, but now we have to learn together."(Interviewee 4)

"The learning trajectory program allows for different ways of reflection." (Interviewee 9).

"Yes. Firstly the book is out there. I can always look into it when necessary because it is all on paper. Secondly, unassumingly, I have been involved with this trajectory. I have been interviewed, and I have been to a COB session."(Interviewee, 2).

On the other hand, the exploitative learning process aims to capture knowledge that can benefit not only the GSP project but also the entire construction industry, as evident from the following statement:

“This and this alone has been the goal of this trajectory, so that we may improve in the sector altogether. Because in the infrastructure industry, we are making mistakes, and we are still not making profits."(Interviewee, 2).

”Yes, you are making your experiences communicable. It helps to explain to others what your experiences have been.”(Interviewee 6)

In one project meeting, success stories were discussed. Subsequently, RWS' employees were asked to present their bad experiences because, within RWS, it is more the culture to discuss errors. Finally, an independent expert ensured that other organizations and project team members' negative experiences were brought forward, for example, by giving a positive twist to ignorance or by indicating the causes of the failure. This created an atmosphere in which negative sharing experiences were no longer scary, and everyone knew that one's own learning experiences would make the project better.

6.4.1.2 Learning on the job

A traditional summative project evaluation is often done in hindsight when it is too late to improve project performance. It has been noticed that most project reflection and lessons learned collection happen when the project is finished, as one interviewee said:

“*We were way too often looking back at phases trying to learn rather than learning on the job." (Interviewee 10)*

It was emphasized that there were no follow-ups in the past. This becomes clear from her statement:

“This means that I feel like I gave a lot, but I did not receive anything back. I did not learn on the job, so to say. There might have been nice lessons learned, but I did not feel this.” (Interviewee 2)

In this case, the learning trajectory program was trying to learn and reflect in an immediate feedback way. This was explicitly mentioned in the following statement:

“This means the learning trajectory program and the project were on a simultaneous line. I could be able to learn far more interactively. I could align the learning trajectory program with the phases in which the project took place so that I might learn while in the project and not after." (Interviewee, 2).

Project team members have not only their technical knowledge but also their past experience. Learning on the job gives access to a much wider breadth of knowledge than they would have from the post-project appraisal, after-action review, micro-articles, learning histories, recall, and other solidification

forms for other projects (Schindler and Eppler, 2003).

6.4.1.3 Mindset change

The head of communications from IXAS believes that the exploitative learning process has led to different working experience. She explained how the present mindset in the project could be conceptualized:

"There is much openness and trust that the problems can be shared and that there is no penalty, but a common goal of solving the problem with RWS." (Interviewee 4).

The interviewees claimed that the exploitative learning process itself has led to a more open and adaptable project atmosphere. This topic is directly taken over from IXAS showcases the close relationship these two organizations have. In reality, the exploitative learning process in their experience was put into place by placing everyone in contact. The project manager from RWS explained this in the following statement:

"What we did was put the key managers into contact with each other. We allowed them to talk with each other and talk about how everything is done, even though everyone is in a stressful period." (Interviewee 10).

When asking about one specific thing that he might have learned from the exploitative learning process, the environmental manager from RWS believed there is a more conscious mindset created. This becomes evident when he stated that:

"The good thing about this is that acts are performed more explicitly because they realize that acts are noted or are passed onto other projects. Because this leads to unconsciously thinking about the fact of why and how you are doing things. The second important effect is that you create a mindset which you develop after sharing the knowledge." (Interviewee 1)

He explained that one of his takeaways to future projects is:

"The insight perhaps, that there is no them and us between contractors and the owner, the motivation for people is often that we want to realize a good result and be proud of the result; this binds us." (Interviewee, 1).

This line of thinking is again stressed through the following statement the contract manager made:

"The added value is not actual facets of the tunnel; the added value is understanding each other, of your role and the whole situation. That is the tricky part about taking a project and knowledge like this into the next project." (Interviewee, 7).

6.4.2 Learning in inter-organizational settings

6.4.2.1 Owner and contractors

The contract manager from RWS experienced the learning trajectory program as a renaissance of the collaborative way in which RWS is already working. She stated:

“The openness and transparency were already present at RWS, but for IXAS, it probably took a bit more effort. It is very brave by IXAS.” (Interviewee 7).

“We always ask what we can do to help IXAS. If we help IXAS, it helps the project.” (Interviewee 7).

RWS set up the learning trajectory program together with IXAS and was partly responsible for executing it. They reflect on their actions and try to alter their behavior concerning the steering of RWS in the project. The project manager from RWS emphasized that the learning trajectory program sets out to allow for a new and different communication method. This becomes evident in the way the project manager of RWS stated the following:

“What I find interesting in this story is that by forming the learning trajectory program this way and have the conversations we had, you can talk with each other differently. If you say you are prepared to share knowledge and be transparent, you create curiosity. If you have a project like this and create a learning trajectory program, you create almost a new steering mechanism. We had a couple of times that before we talked with the COB, we were already talking about what we were going to discuss. It makes you think. If you can talk about all the experiences you had, you create another management tool.” (Interviewee 10)

Why is a private organization like IXAS willing to share its knowledge is bound to the IXAS culture of knowledge sharing? An interviewee from IXAS answered:

"Let me tell you something interesting. Construction organizations do not know the worth of knowledge, and they do not live on knowledge either. They can produce knowledge and produce goods. However, they do not know what knowledge they are producing. We are no knowledge organizations. We are prepared to share knowledge because I know that I am again working with the same people in the next project." (Interviewee, 6).

Within the RWS project organization, the importance of collaborations is exemplified because of a specific RWS culture, framed as the alliance culture. This culture is described as being an open culture in which there is an “us” and not a “us” versus “them.” The observation that the word RIXWAS was created showcased the closer relationship between RWS and IXAS. RIXWAS refers to an intertwining of IXAS and RWS (also referred to as 'colleague model'). A clear commitment has been made to the project strategy.

IXAS sets out to be adaptive, resulting in the openness and willingness to share. Therefore, the project management proceeded with caution and ensured a familiar environment where people felt safe to tell about their negative experiences. A few meetings were arranged, such as project start-ups, project follow-ups, and other alignment sessions in which both RWS and IXAS were deemed to be present. These meetings allowed the participants to view how the project had been going, which was aligned with the learning goal that the learning trajectory program set out to achieve.

6.4.2.2 Members within the contractor consortium

The project manager from IXAS exemplified how the learning trajectory program was a great team-building tool. The fact was highlighted that regarding the employees' backgrounds from the three organizations that form IXAS, there was also no discussion of “us” and “them," just like the relationship between RWS and IXAS. It was stated that:

"There were no talks about them and us, Ballast Nedam, Fluor, or Heijmans (the three contractors of IXAS). I did not experience that at all. This also led to the learning trajectory program, as the need to share and learn from this open culture. So there was also much courage needed from our perspective and from RWS to speak to our superiors and say that we are going to do it this way, and we stand apart from the “parent" organizations."(Interviewee, 2).

“We let go existing company cultures” (Interviewee 9).

The director of IXAS experienced the learning process as something which focuses on softer knowledge. He referred to this as:

“But how you deal with the culture, people, and companies to create a huge project in a short time that is a competency that is interesting to understand. That is, also depending on the people and situations." (Interviewee, 8).

When asking the project manager from IXAS about this argument, he answered by stating:

“Of course, it is. If there is no willingness from both sides, it is not possible. We hardly used the contract in our meetings. That is only used in disputes. We are open to sharing knowledge because of this mentality.” (Interviewee 9)

6.4.2.3 External knowledge party

Three learning networks were formed: 1) the safety network, 2) industrial integration automation, civil engineering network, and 3) environment management network with key figures at IXAS and RWS. The COB team held in-depth interviews per network and collected documents for the exploitative learning process. They analyzed what exactly the learning vision was, how that vision had been worked out in a

plan of action, what the essential tools were and would become, what the experiences were in practice and what could be learned from them. The learning trajectory program results were written out and added to the various chapters of the COB books. The chapters were submitted to experts from five large infrastructure projects, including A2 Maastricht, Combiplan Nijverdal, Zuidasdok, A16 Rotterdam, and Blankenburgtunnel. Academics were also invited to review the material and enrich it from their own scientific perspective.

Project managers from both RWS and IXAS emphasized that the COB team members inspired them to bring lessons learned to the light and share them. Some managers involved in the project might not reflect on their actions and on the project themselves because they are too close to the project and therefore find it challenging to keep an overview.

The tunnel technical manager from RWS believes that an external knowledge party like COB can look at the project from an outsider's view and explain to this manager what he could not visualize himself. He explained this in the following statement:

“Many things I just do the way I do it. I have done it before and will do it the same way. If you ask me what happened, I will just start talking about what I did. Moreover, an academic will then point to something and talk about something that would be reflected upon. I cannot do that myself. The professor gets something out of the ordinary activities that I cannot by myself." (Interviewee, 5).

It was also mentioned how the COB team pushed them to generate and share knowledge during the project. Two books, written by COB, were handed to various projects to learn to switch from exploitative learning to inter-project learning, and this would allow for dialogue sessions to happen. The books would allow these different projects to contact people from the GSP project in case of questions.

6.4.3 Project-based organization and parent organization

It is essential that lessons from projects eventually are structurally fed back to the organization (Sydow et al., 2004; Terry Williams, 2008). The project managers from both the owner and contractors are in a position between the parent organizations and the project. This separation from the parent organization could also be felt at IXAS. The former environmental manager IXAS emphasized the separation between the RWS representatives in the project and the parent organization of RWS by stating:

"I also believe that we were more innovative and braver than RWS initially." (Interviewee 2).

There is a difference in the level of learning from the perspective of the IXAS director:

"Yes, but on different levels, some just take with them knowledge on "smaller," more basic acts and on working experiences at the tunnel. They might take some of these lessons very literally to the next project.

What we are talking about is, this might sound a bit common, but we are at a different level." (Interviewee, 8).

The physical dissociation from the relative political and bureaucratic permanent organizations appeared to lead to a confidential and safe environment that encourages learning within the project and results in successful projects. This is in line with the approach in the Sluiskil Tunnel project. The different distanced locations created, however, hinder learning between the project and permanent organization.

6.5 Discussion

6.5.1 Exploitative learning in the inter-organizational project

RWS and IXAS both had a positive experience with the exploitative learning process. Many managers stated that learning in the inter-organizational setting has come as a result of alliance formation and evolution. Participants work together will eventually come to learn from each other, even in cases when alliances are not established with learning intentions (Grant and Baden‐Fuller, 2004; Muthusamy and White, 2005).

Our findings join the discussion on the project learning paradox (Bakker et al., 2011a). The inter-organizational project shows that the form of tacit knowledge in projects cannot be easily copied and pasted to another project. In contrast to the hard procedural and technical side, there are lessons learned aimed at a professional collaboration. Learning can be a useful management tool for project management (Chow and Chan, 2008). People perform better and are more motivated when they feel that their opinion matters.

According to interviewees, many actors in this inter-organizational project will re-appear in other big projects as well. The experiences lie mostly in the people, which would mean that the lessons might not get lost at all. People themselves might be the most extensive knowledge asset that can be transferred to other projects. In that sense, the knowledge lies within practices and can be shared. The past influences the temporary effects of inter-organizational projects (Ligthart et al., 2016). The project collaboration experience and the reduction of future transaction costs are the driving factors for establishing repetitive participants by temporary organizations (Ebers and Maurer, 2016). The learning goals will be reached in the bigger picture.

However, there is a difference in the way that lessons can be applied to other projects. This difference is partly influenced by the level at which one operates in the inter-organizational project. The infrastructure development project can be seen as a temporary organization that considers the parent organization as the most important stakeholder. Such a project is successful when the parent organization receives appreciation, measured by how well the project implements and supports its business strategy (Artto et al., 2008).

There are many contradictions between temporary organizations and permanent organizations. Learning boundaries are an essential constraint on exploiting project-based learning benefits for the broader organization (Scarbrough et al., 2004). Burke and Morley (2016) outlined four central contradictions, pointing out the problem of knowledge being transmitted in a broader permanent organization. The multi-level layers of the inter-organizational project affect learning as they tend to act as learning boundaries. We are sensitive to the practitioners' double obligation towards their parent organization and towards the inter-organizational project in which they are involved. Projects operate relatively autonomously from their parent organization. The parent organizations were almost entirely left out of the exploitative learning process in this case. Our research explained how the owner and contractors' members stood closer together than their parent organizations.

6.5.2 Collaborative project culture shaped by learning

Often it is only after the occurrence of a significant adverse event that a change in mindset happens (Zimmermann and Renaud, 2019). The exploitative learning process, in this case, introduces a proactive attitude, conceptualized as a "mindset change," with which people have started to think and discuss more things. This mindset is also partially a requisite for the exploitative learning process to succeed in the first place.

Organizational culture plays an essential role in motivating and facilitating learning from projects (Prencipe and Tell, 2001). Our study demonstrates that there is a reciprocal relationship. Learning from scratch, rather than with lessons learned from other projects or at the end of the project, has given participants a vital sense of involvement needed to start things up. The owner is mainly responsible for establishing the culture, and all parties should maintain the culture. Culture creates norms regarding what is encouraged in the project and influences how people communicate and share knowledge. Edmondson (1999) observed that the better performing teams admit to errors and discuss their occurrence - a climate of openness.

This suggests that learning has socially constructed values or meanings. Most interviewees focused more on the possibility of creating the right project culture to allow for the exploitative learning process to function. Organizational culture in the project can be referred to as existing out of practices, symbols, values, and assumptions that members of an organization share regarding appropriate behavior (Willmott, 2011). The culture of RWS in the inter-organizational project has been conceptualized as an alliance culture. This refers to a culture in which working together is the norm. Exploitative learning behaviors can also shape the project culture. In this sense, exploitative learning behaviors are embedded in the project culture present in both the owner and contractors. The culture shapes the members' learning behaviors and influences how they learn and adapt it (Lekkakos and Robertson, 2009).

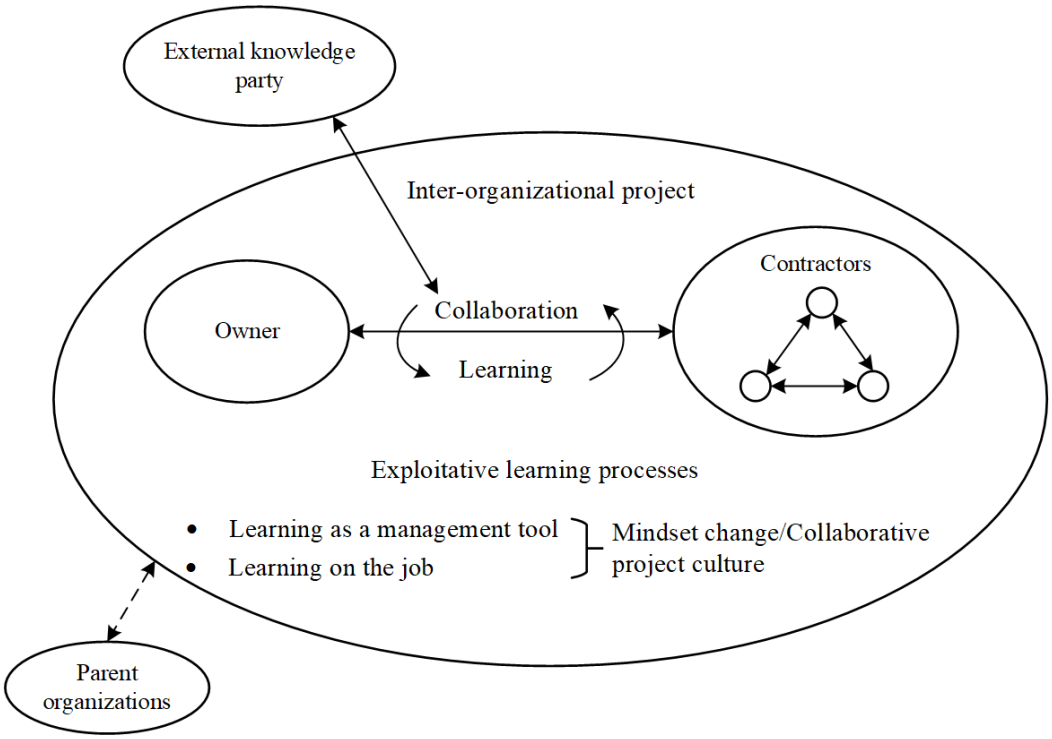

Figure 6.1 Exploitative learning in the inter-organizational project

We came up with the theoretical framework by bringing key exploitative learning actors in the inter-organizational project (see **Figure 6.1**). It is also a combination of three learning processes: experience accumulation, knowledge articulation, and knowledge codification (Prencipe and Tell, 2001). First, by working on the project, project actors automatically accumulated experiences. The GSP learning trajectory program sought to develop ways to manage knowledge articulation from scratch. Tacit knowledge becomes verbally articulated through performance reflection as a management tool and learning on the job. Learning happens both between the owner and the contractor and internal within the contractors. The external knowledge party is needed to stimulate and facilitate the trajectory continually. They are necessary as an impartial body to establish the dialogue. The owner and contractors tried to implement a move away from the traditional way of thinking towards a more collaborative culture. Learning is observable through the impact on the culture at the project level. Some studies suggest that collaboration enhances exploitation (Scarbrough et al., 2004), while our research found that exploitation can, in turn, enhance collaboration. Exploitative learning in the inter-organizational project can enable sharing of knowledge and lead to a common understanding, which generates a higher order of collaboration (Otra-Aho et al., 2019, 2018). The collaboration is a direct result of this shared project culture, as in practice, this collaboration was experienced as very open and friendly. However, it is found that this project culture allows these members to stand apart from their parent organizations to a certain degree. Wiewiora et al. (2013) argued the need to investigate the role of subculture in transferring knowledge from projects to project-based organizations. This also means that these different types of

culture and ways of working at different levels of organizations do not always go hand in hand with each other (Ajmal and Helo, 2010).

6.5.3 Implications for the future

There is a strong sense of having a collaborative project culture that is shared by both organizations. Project culture will transcend the organizational culture. The inter-organizational project is centered on having an open and inclusive mindset, which is needed to experience the exploitative learning process. They need to be open to receiving feedback from an unexpected angle, and they need to have the courage to ask for opinions from different people. The motivation behind this is the philosophy that by working together this way, the result can be more than just the sum of its parts and lead to innovative knowledge co-creation (Liu et al., 2019). To bring this knowledge to another project, the right culture needs to be in place at that organization for the exploitative learning process and the new mindset.

RWS and IXAS have indicated that they want to use their knowledge and experiences in their own projects and share it as a source of inspiration. In this case, the involvement of parent organizations was minimal. The organizations need to focus on people's learning initiatives, not on collecting data, because knowledge resides in the people (Davison and Blackman, 2005; Rubenstein-Montano et al., 2001). The best way to share this knowledge is by putting a person with their experiences in another project where the knowledge can be implemented. It can enable exploitative learning in the inter-organizational project, leading to the project's continuous improvement to meet business goals. Future research would be needed to find out more about possible added benefits of adding parent organizations' involvement in a similar exploitative learning process (Riis et al., 2019).

6.6 Conclusion

In this research, we investigated how exploitative learning was promoted in the inter-organizational project. The learning trajectory program (exploitative learning process) has been experienced generally positively as a continuous “learning-in-practice” phenomenon during the project. During this collaboration, there were lessons learned from each other as well, and this line of thought fits with the learning process. Learning helps better understand dilemmas and their origins. Further, learning should occupy a more dominant role to create a collaborative culture in the specifically challenging project environment during project development.

According to the empirical data, the most significant change that the exploitative learning process has led to is the change in mindset. One of the conclusions is that learning stimulates openness, and this has a positive impact on more collaboration, which echoes the theory about collaboration from Hertogh and Westerveld (2010). A collaborative culture and understanding of each other’s roles in the inter-organizational project will lead to a better project. The mindset of creating a stable and trusting

relationship with the owner and contractors was the most significant effect the exploitative learning process had on them, beyond the technical expertise, thus the biggest piece of knowledge the project participants would take with them to future projects. The knowledge learned in this inter-organizational project is bound to the people that have experienced it. There is a reciprocal relationship between learning and collaboration. Collaboration can enhance learning, while learning can facilitate collaboration. Our findings confirmed this theoretical relationship and suggested to cultivate a culture of promoting learning in future projects. In this sense, collaboration is the fifth discipline in project-based learning (Senge, 1990).

This research responds to the debate about project-based learning. The study fits in with various discussions on learning in and between projects (Bakker et al., 2011a; Hartmann and Dorée, 2015). Within the construction sector, learning seems not to be widely achieved (Flyvbjerg et al., 2002; Hertogh et al., 2008; Lindner and Wald, 2011). Because of the focus on projects, there is an institutional distance between the project and its organizations, which hinders learning. The learning within the project team is not only done to solve the problems encountered in the project. What was learned by the project participants was somewhat more bound to soft knowledge. The collaboration was experienced as predominantly positive and personal in the case. We view exploitative learning as a meaning-making endeavor. Learning gives meaning to what is happening in the project. In that sense, it is also the carrier of the collaborative culture in an organization. This exemplifies the project culture that was shared and the mindset which would be brought to future projects. The concluding remarks seek to establish a reciprocal relationship between a collaborative project culture and an exploitative learning environment to motivate employees to communicate and share knowledge and expertise with their colleagues and across the supply chain instead of working in silos. It can be exciting to follow-up with the increasing parent organizations' involvement of both the owner and contractors in a similar exploitative learning process in the future and test its effects.

The research was conducted in a Dutch context. Dutch participants perceive open discussion as a standard way of working. It is related to the Dutch roots, which result in a more free mentality with a focus on its employees' well-being. Besides, egalitarianism is emphasized in Dutch culture. It does not aim to select the best among potential solutions but instead devotes energies to consent on a recommended one. It is suggested to align the findings presented with the experiences of construction organizations in other parts of the world.

Appendix 6.A Activities for participant observation

Table 6.2 Activities for participant observation

Date	Meeting	Present	Topic	Number of participants

9-03-2015	Alignment session	IXAS and RWS	-	-
10-12-2015	COB congress, presentation	Sector	Results evaluation tender and dialogue phase	100
20-04-2016	Group discussion	IXAS and RWS	Progress knowledge project with management	6
21-06-2016	Alignment session	IXAS and RWS	Challenges in the project	18
09/10-2016	Interviews knowledge session	IXAS and RWS	Environmental management, tunnel safety, relationship TTI civil	-
21-11-2016	Group discussion	IXAS and RWS	Sharing lessons with management knowledge project	8
08-12-2016	COB conference, various presentations	Sector	Learning trajectory program, environmental management, technical tunnel installations	100
07-03-2017	Alignment session	IXAS and RWS	Content sparring and preparing and knowledge day	35
27-03-2017	Knowledge Day	Sector	Share and discuss knowledge project	150
22-09-2017	COB café	Sector	Presenting COB books and plenary discussion	100

Appendix 6.B Interview protocol

Objectives: 1) To explore the experiences of actors from RWS and IXAS in the learning trajectory program; 2) To determine whether the learning trajectory program has led to observable changes in practice; 3) To examine the role of organizational culture in the effectiveness of the learning trajectory program

1. Present function in the GSP project
    - Their expertise in their respective field
    - Their function within the project (development of the GSP project)

Theme 1. Experiencing the learning trajectory program

2. Expertise in the learning trajectory program.
    - Their description, in their own words, of the learning trajectory program
    - What are the goals of the learning trajectory program in their own opinion?
    - Have they been informed about this learning trajectory program, and if so how?

3. Personal partaking in the learning trajectory program
    - Their partaking in the learning trajectory program
    - The success of the learning trajectory program in their eyes
    - The satisfaction of their own partaking in the learning trajectory program
4. Experiencing the learning trajectory program
    - Anything that you would like to have seen differently in the learning trajectory program?
    - Their satisfaction with the learning trajectory program
    - One thing that has stuck with them the most from this learning trajectory program
    - Has their experience with the learning trajectory program been positive, negative, or rather a mix of both?

Theme 2. The changes in practice due to the learning trajectory program

5. Observable changes in practice
    - Previous experiences with the learning trajectory program
    - Their belief in the helpfulness of the learning trajectory program for themselves and/or for the project
    - Possible significant differences in behavior from themselves or their colleagues due to the learning trajectory program
    - What have they learned during this learning trajectory program of learning?
    - Name one valuable lesson if possible
    - Possible changes to the way of thinking about any aspect of the project due to the learning trajectory program
6. Applicability of the learning trajectory program for future projects
    - Their view on the usefulness of such a learning trajectory program for the GSP project
    - Possibility of lessons learned to be transferred to other projects
    - Personal lessons learned that they would take themselves, or are already taking, to other projects.

Theme 3 Collaboration with the opposing party

7. Collaboration with IXAS/RWS
    - Their description of the collaboration with IXAS or RWS
    - The role of the learning trajectory program in this collaboration
    - Experiences with this collaboration until now
    - Would they have collaborated differently if they knew what they know now and would have experienced what they have experienced up until now?
    - (For RWS stakeholders) The extent to which they have learned and applied any new methods such as the safety topic from IXAS
    - (For IXAS stakeholders) The extent to which they have learned and applied any new

methods from RWS

- Their view on whether this possible learning and applying is a result of the learning trajectory program or a result of their own organization

Theme 4 The role of culture in the project and the learning trajectory program

8. The role of culture
    - How they see or experience culture
    - Their description of their own organizational culture, if they experience it.
    - Describe the opposing culture, if they experience it
    - Their beliefs on the existence of a temporary project culture which both IXAS and RWS could experience and operate within
    - If indeed experienced, their description of this culture.
    - (For RWS stakeholders) the possibility of a difference between this project culture and the (broader) RWS culture (meaning RWS outside of the GSP project)
    - (For RWS stakeholders) The possibility of a difference between the project culture within the (broader) RWS culture
    - Their views on the learning trajectory program being a result of their own culture or rather the learning trajectory program shaping their culture

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Chapter 7 Explorative Learning in the Infrastructure Development Megaproject: a Case from the Hong Kong-Zhuhai-Macao Bridge

Abstract

Research on explorative learning has been focused primarily on the organizational level. Not much research has been done at the temporary project level, especially the infrastructure development megaproject level, a more complex form of organizing. Therefore, it is advisable to analyze how the pursuit of explorative learning is enabled at the megaproject level. This research draws upon the case study of the Hong Kong-Zhuhai-Macao Bridge (HZMB), a cross-sea link construction project, to study how explorative learning was achieved and sustained. The findings from archival documents, interviews, and focus group discussions indicate that the megaproject is more likely to increase complexity but might bring value via more significant learning opportunities. Explorative learning is enacted through the complementary use of owner leadership, collaboration, external resources, and experiment. This research adds to our knowledge of how explorative learning works in practice and highlights its significance for the megaproject context.

Keywords: Megaproject; explorative learning; complexity; learning strategies; HZMB

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7.1 Introduction

Infrastructure development megaprojects are characterized by their unique and one-off nature, long-term design and construction cycle, and high organizational, technological, and environmental complexity (Bosch-Rekveldt et al., 2011; Geraldi et al., 2011). The infrastructure megaproject has always had the ambition to execute the project on time and within budget. To achieve that goal, project-based learning is essential in achieving and sustaining a competitive advantage. It is crucial to take advantage of lessons learned from projects and partners to avoid re-inventing the wheel. It is difficult to apply general project management methods to megaprojects directly. However, it has been acknowledged in the literature (Carrillo et al., 2013; Savelsbergh et al., 2016) that it is challenging to learn in the project context, not to mention in programs and megaprojects.

Chronéer and Backlund (2015) argue that despite the rhetoric from all sides about how important learning is for business growth and innovation, the practice of learning that delivers these results is challenging to find empirically. We notice some problems with the current framing of learning in megaproject studies. First, a post-project evaluation of learning with much knowledge gained but lost may restrict our understanding of managing learning. An erroneous project evaluation may create a "lock-in" (Cantarelli et al., 2010). Second, a narrow view of avoiding making mistakes may downplay the value of learning provided by the complexity of the megaproject (Bledow et al., 2009).

Explorative learning aims to explore the unknowns, generate new knowledge, and create novel solutions (Brady and Davies, 2004). There is a gap in our understanding of the underlying mechanisms and dynamics by which organizations can achieve exploration. The question of project learning remains unresolved from our perspective, given the persistence of the low level of project success. For the megaproject, research avenues remain largely to be explored. Little is known about the functions and roles of the actors in project-based explorative learning involved in megaprojects. We address the following research question: What critical strategies should be developed to promote explorative learning in megaprojects?

The research is organized as follows. The literature review section focuses on the characteristics of megaprojects and the theoretical background of explorative learning. The research aims to stimulate discussions about how explorative learning contributes to the infrastructure development megaproject management and its practice. In the methods section, a case study of the Hong Kong-Zhuhai-Macao Bridge (HZMB) project is elaborated. The results section provides evidence for the topic. The relationships between explorative learning strategies are revealed in the discussion section. The research concludes with theoretical value, practical implications, and research limitations.

7.2 Literature review

7.2.1 Complexity in megaprojects

A megaproject is often defined as complex system with budgets over $1 billion involving many private and public stakeholders and impacting millions of people over a long period (Brookes et al., 2017; Flyvbjerg, 2014; Flyvbjerg et al., 2003). Megaprojects are inherently risky due to long planning horizons and complex interfaces. They require unique and integrated structures. The specific characteristics of megaprojects that shape learning practices (Sergeeva and Roehrich, 2018) are being bespoke (created for a particular purpose), one-off (specific end date, but usually long lifespan with multi-organizational interfaces; at the end, megaproject members separate and not always work together on subsequent megaprojects) and different organizational roles (e.g., clients/owners and suppliers).

Based on the above characteristics, adopted technology and designs are often non-standard in megaprojects, leading to uniqueness bias among planners and managers, who tend to see their projects as singular, which impedes learning from other projects (Flyvbjerg, 2014; Li et al., 2018).

The uniqueness of the task and the project's complexity can lead to uncertainty of the project (Burke and Morley, 2016; Tatikonda and Rosenthal, 2000). The more unique the tasks faced by project members, the less prior experience they can use. They have to experiment and innovate in action, which makes the development of the project unpredictable. Simultaneously, some tasks cannot be accurately defined at the outset and can only be gradually formed into clear outlines during execution (Lundin and Söderholm, 1995).

The nature of megaprojects brings together significant tacit knowledge embedded within particular participants in the project (Bresnen et al., 2003). There is often over-commitment to a specific project concept at an early stage, resulting in lock-in, capture or early convergence, leaving analyses of alternatives weak or absent, and leading to escalated commitment in later stages (Bakker and De Kleijn, 2014; Hertogh and Westerveld, 2010).

Megaprojects are application areas for theories and tools developed in project management research. Considering the extraordinarily complicated and non-routine characteristics of megaprojects, a new approach is required to make it flexible, adaptive, and pursue new knowledge and technologies (Geraldi, 2009). Complexity raises the need for learning to develop new ranges of adaptive solutions when circumstances change (Eriksson et al., 2017a). Megaprojects can be socially constructed as opportunities for learning through the way people communicate, interact, and share knowledge in the context of project alliance organizing (Hartmann and Dorée, 2015). Explorative learning can facilitate identify and test new technical solutions and organizational processes (Lenfle and Loch, 2010; Perminova et al., 2008).

7.2.2 Explorative learning in projects

There is a range of different perspectives in the literature that investigate the mechanisms and processes of how knowledge is generated, utilized, and transferred. A severe debate exists on the ambidextrous view, the capacity to organize the high level of explorative learning and exploitative learning in the management science (Duncan, 1976; Levinthal and March, 1993; March, 1991). Exploitation and exploration are two different learning activities (March, 1991). Exploitative learning focuses on multiple experiences and existing solutions in order to achieve high levels of consistency and efficiency, whereas explorative learning is characterized by experimentation and innovation to generate novel solutions (Eriksson et al., 2017b; Eriksson and Leiringer, 2015). Therefore, exploitation involves activities characterized by refinement, efficiency, and execution, whereas exploration involves activities characterized by search, discovery, experimentation, and innovation (He and Wong, 2004). A certain tension exists between these two activities. Exploration and exploitation compete for rare organization resources. Exploration and exploitation need different organizational structures, processes, strategies, capabilities, and culture (Zhou and Xue, 2013).

Davies and Brady (2016) identified two types of projects: routine projects and innovative projects. The former exploits proven technologies and mature products, and addresses current customer demands, achieve predefined goals with a given set of resource constraints (time, cost, and quality). Routine projects rely on traditional forms of project management based on compressed sequencing tasks and economies of repetition to achieve the reliability and predictability. While the latter supports explore innovative alternatives, test new ideas and technologies in uncertain environment. Innovative projects deal with highly unforeseeable conditions when the means to achieve the objective are too difficult to define at the outset. Loch et al. (2011) had a similar proposition to identify “simple projects” that address predictable and repetitive tasks, and “novel projects” that deal with unforeseen uncertainties, which separately focused on exploitation and exploration. Megaprojects, which always are innovative projects, are always challenging to plan well in advance and involving high degrees of novelty and complexity.

Davies et al. (2016) linked uncertainty to the exploration side. Conventional planning and control tools can efficiently perform routine tasks, but they face significant limitations when encountering highly uncertain tasks (Lenfle and Loch, 2010). Higher levels of uncertainty lead to more significant opportunities for learning (Cooke-Davies et al., 2007). If an organization can tap into the rich possibilities afforded by complexity, it can turn learning into achieving business value.

Standardization, control, and analytical tools emphasized by traditional project management are not directly derived from significant early projects, but more because of the commercialization of project management by Project Management Institute and the promotion of leading project management advocates, e.g., the US Department of Defense. It should be noted that regular tasks and highly uncertain

tasks should be distinguished, and the two cannot use the same management tools and methods. The distinction between the two types of learning appears to be between learning achieved through disruptive activities and learning attained incrementally. For highly uncertain tasks, trial and error, iteration, parallel testing, and selection, which belong to explorative learning, can be used. It is a useful strategy in studies (Browning and Ramasesh, 2015; Ramasesh and Browning, 2014) on reducing unknown unknowns.

7.3 Methods

7.3.1 Research design

A case study approach has been defined as an empirical inquiry investigating a phenomenon within its real-life context, when multiple sources of evidence are used and when the boundaries between phenomenon and context cannot be seen (Yin, 1983). In practice, the HZMB project offers an immense opportunity for research on the learning process of infrastructure development megaprojects' management practices. The case study approach was chosen because it fits the interpretative and qualitative nature of this research, and it is suitable to study complex phenomena (Dalhammar, 2003; Klein and Myers, 1999). The research method combines historical analysis of the key events in the megaproject and a content analysis of the key stakeholders' narratives. Such various data sources combined with the deep engagement with the field have been reported to lend themselves to insightful inductive theory building (Gioia et al., 2013).

7.3.2 Case description

The HZMB project is chosen because it is a particularly well-suited case to examine megaproject and explorative learning. The 55 km long HZMB is situated at the Pearl River Estuary of the Lingdingyang Sea, which consists of a dual three-lane carriageway in the form of a bridge structure, an immersed tunnel of about 6.7 km, two artificial islands, and two link roads in the east and west of the estuary (see **Figure 7.1**). HZMB links the Hong Kong Special Administrative Region, Zhuhai City of Guangdong Province, and the Macao Special Administrative Region in China. Construction formally began in December 2009, was completed in May 2018, and opened to the public in October 2018. The total cost of the main bridge was approximately 127 billion RMB ($18.63 billion). It is both the longest sea-crossing and the longest open-sea fixed link all over the world.

The justification for focusing on HZMB relates to its status as a pioneering ecosystem for developing the combination of reclamations, artificial islands, immersed tunnels, marine viaducts, and cable-stay bridges. Its design has been driven by aesthetic, environmental, engineering, and durability aspects. The route of HZMB has passed the busiest main channel in the Lingdingyang Sea. The bridge comprises three navigable bridges and 20 km of non-navigable bridges. The environment decided the bridge must be a suspension bridge with a large span, a high clearance, and a tower. Simultaneously, the location is

close to the Hong Kong International Airport, and the height of the structure in the aviation area restricts large-span, high-tower structures. Therefore, a tunnel is the only viable option. To realize the connection between the bridge and the immersed tunnel, two artificial islands are constructed at both ends of the tunnel. During the development, the project has been faced with many world-class technical challenges, including the rapid formation of offshore artificial islands, tunnel foundation treatment and settlement control, immersion and docking of tunnel sections, large scale factory production, embedded pile cap installation, watertightness for underwater construction, extensive pavement work on the steel bridges, and system integration for the traffic engineering, etc. Given the scale, complexity, and sensitivity of the project, advanced technologies and management philosophies were adopted to develop innovative systems and mechanisms, and excellent design, construction, and consultancy companies were invited to build this remarkable project. The contentious nature of the case involving sensitive political and commercial issues makes it very difficult to research (Smyth et al., 2018). **Table 7.1** shows the main participants making up the HZMB project organization.

Figure 7.1 HZMB map (Source: South China Morning Post)

Table 7.1 Participants of main work of HZMB

Sections	Leader	Members
The general contractor of design and	China Communications	CCCC Highway Consultants

construction of artificial islands and tunnel work	Construction	AECOM Asia
		COWI A/S
		Shanghai Urban Construction Group Corporation
		Shanghai Tunnel Engineering & Rail Transit Design and Research Institute
		CCCC Fourth Harbor Engineering Investigation and Design Institute
Design and construction consulting of the HZMB main work	Shanghai Municipal Engineering Design Institute	TY. Lin International Group
		Tunnel Engineering Consultants (TEC)
		Guangzhou Metro Design & Research Institute
Bridge Engineering Construction Drawing Design of HZMB main work	CCCC Highway Consultants	Chodai
	China Railway Bridge Survey & Design Institute	Halcrow Group

7.3.3 Data collection

For the case, three primary data sources were used: access to the archival documents, interviews with senior stakeholders, and focus group discussions. It proceeded in an inductive and exploratory manner (Siggelkow, 2007).

We focused on seeking events that facilitated learning. Luckily, we could access an internal project magazine named “HZMB Bridge” run by the HZMB Authority. The magazine has been compiled six times a year from 2011 to 2017. All articles in the magazine were stored and categorized in a database that enabled searches for keywords and topics, which facilitated our empirical analysis. We searched the empirical material for critical events (Flanagan, 1954) during which actors faced challenging problems and learned to find situations. Initial extraction of the data set resulted in all learning-related events from the case, which we called learning action episodes. Each episode is a snapshot in time, encapsulating a moment that includes a set of activities resulting from learning (Gardiner et al., 2018). A learning action episode can relate to any project actor or event, including risk-taking, distant search, and experimentation. The learning action episodes are outlined as activity configurations (Regnér, 2008), which means a collection of actions that form a set of activities observed and analyzed by the researcher. In a learning action episode, all relevant direct and indirect data should be available so researchers can analyze and assess what has been learned and what has been improved. The intended outcomes of a

learning action episode are solved problems and enhanced project team capabilities. We do not guarantee the examples represent an exhaustive list, but they indicate explorative learning.

Following case study research guidelines, one of the essential information sources are the interviews (Yin, 1984). The purposive selection of interview samples is essential in qualitative research (Schwandt, 1996). The primary contact helped identify and get approval for people to be interviewed, and we also adopted snowball sampling as the interviews progressed (see **Table 7.2**). For interviews to be productive, it is essential to encourage interviewees to speak openly. Interviewees reflected on their project management and learning process and added more details to the learning action episodes. The interviews varied in duration but ranged between 30-90 minutes.

Table 7.2 Data source

Interviewees		Number
Type	Organization	
Owner	HZMB authority	3
Contractor	China Communications Construction Company	2
Consultant	Tunnel Engineering Consultants (TEC)*	2
Consultant	The strategic advisory team	3

* TEC is a joint venture partnership between Royal Haskoning DHV and Witteveen+Bos. TEC was the key consultant for designing and constructing the immersed tunnel and the artificial islands.

The purpose of the focus group discussion is to validate the findings from document analysis and the interviews. Two focus group discussions were arranged separately at TU Delft in the Netherlands, involving more than ten representatives from the general contractor, consultants, and at the HZMB authority in Zhuhai, China, involving five representatives from the owner and the consultants. The focus group discussions allowed the respondents to share their experiences and opinions on explorative learning and megaprojects. Besides, five webinars in total with different themes hosted by the authors and the deputy director of HZMB authority were held over three months from April to June 2020.

Other press coverage about interviews with top managers in professional outlets and academic articles, promotional and documentary video, technical management system and HSE (health, safety & environment) management system documents, as well as a set of visits to the projects, were also used to triangulate the information provided by the direct data and interviewees, add contextual and validated information to the analyses.

7.3.4 Data analysis

Our unit of analysis are the project actors' actions and interactions concerning learning action episodes.

First, we identified multiple specific learning action episodes within the megaproject by coding the learning practices. We searched for patterns over time in our codes and compared them with the learning action episodes. Supplementary stakeholder interactions helped corroborate and provide nuance and contextual insights into the information gathered from the learning action episodes. By analyzing the learning action episodes with the help of stakeholder interviews and focus group discussions, we identified the core event, (interviewee) terms and concepts. We conceptualized them into more abstract concepts with similar characteristics and related meanings. As our study progressed, the data collection became more analytical as we began testing ideas and concepts derived in our interpretation of the data already collected. We did so in an iterative manner to fine-tune the coding. Megaproject dynamics reveal the emergence of key events that impact project decisions and outcomes (Hertogh and Westerveld, 2010). The megaproject's different 'moments' make it possible to consider the megaproject as a set of episodes or short-term events (Ruuska et al., 2011). We centered on the learning action episodes to make sense of our data and from additional data from stakeholders' interactions to explore the consequences of these learning action episodes. The analysis was conducted by synthesizing emerging patterns or themes by considering all the empirically derived series of short-term learning action episodes embedded in a more comprehensive megaproject history. The purpose was to develop a higher level of abstraction and conceptualize how the various codes may be related and labeled to reveal patterns of evolutions initiated by the various stakeholders. **Figure 7.2** displays how the analysis progressed from raw data to the themes with examples. The data structure allowed a configuration of the data. Our interpretations and discussions of the concepts enabled identifying four strategies of explorative learning in the megaproject.

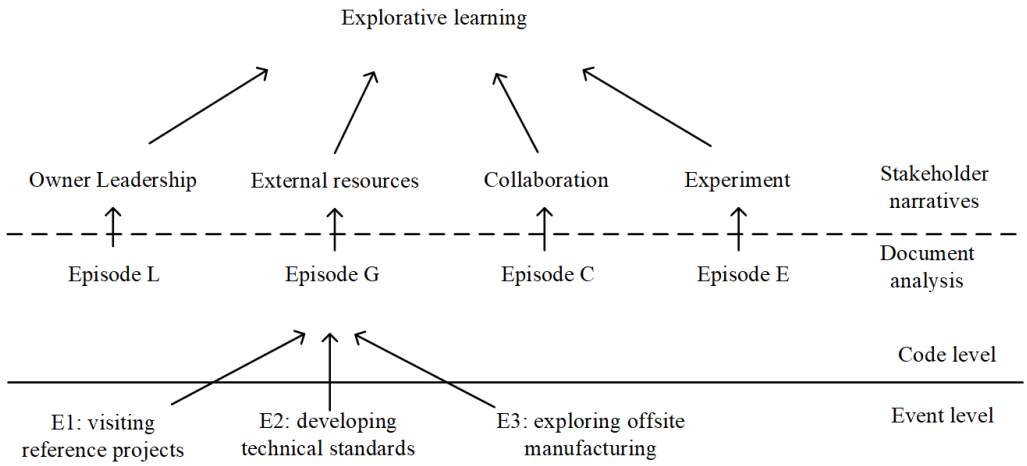

Figure 7.2 Data structure showing events, categories, and themes

7.4 Results

7.4.1 Project complexity and innovations

The megaproject is complicated, risky, and has high goals. Highly innovative projects need to be

managed differently. According to the HZMB Authority interviewee, the construction of the bridge part would answer the question if a “good” or “better” bridge can be built. Steel box girders are used extensively in the bridge sections' superstructure for the first time in China, and the amount of steel required reached 400,000 tons. In line with the philosophy of mechanization and automation, brand new production lines were established, and welding robots and computer-controlled procedures were developed to fabricate plate panels. Factories were also set up in Zhongshan City to assemble the deck sections. For manufacturing the steel towers for the navigable bridges, contractors developed automatic welding machines adaptable to different welding conditions. To alleviate the negative impact on the river regime, channels, and currents, 190 pile caps were embedded within the seabed. This is the most effective application of such a design feature to date in China. The concrete pile cap and pier shaft elements for the non-navigable bridges and the concrete deck slabs for the composite steel box girders were all precast in yards.

As no design and construction firms worldwide had experience constructing immersed tunnels under the open sea conditions, the construction of immersed tunnels would answer the question of whether HZMB can deliver a “successful” or “unsuccessful” tunnel project. The tunnel section of HZMB is the first large offshore immersed tunnel in the history of China. The tunnel sections were precast in Guishan Island's yard in Zhuhai, the world's largest immersed tube prefabrication plant. The yard has two assembly lines and altogether has precast 33 sections of immersed pipes for the tunnel. Precasting the tunnel sections started on May 7, 2012 and was completed on December 26, 2016. The tunnel alignment crosses an area of soft grand, and the tunnel sections were installed as deep as 46m below sea level. To meet the strict precision requirements, the contractor has developed many key technologies and significant equipment. For example, the world's biggest gravel laying and leveling jack-up barge have been designed to lay the tunnel foundation's grand bed.

7.4.2 Learning by owner leadership

In July 2010, the HZMB authority was established as the project owner agent and was mainly responsible for its delivery and operation. It is noted that the HZMB authority created an appropriate communication and knowledge exchange environment. One top manager from the HZMB authority summarized managing the project as “*the owner's positioning of the project, the owner's thinking and mind in the organizational management determine the megaproject's success or failure*."

The HZMB authority chose the general contracting mode to organize the artificial island and tunnel section. It is the critical starting point to find a contractor with sufficient construction capability and the ability to resolve risks. A learning action episode is identified in this phase. It took two years to plan and carry out the tender process. In the first round of tender, there were eleven potential contractors. After evaluating their performance and experience in hydraulics engineering, the candidate number finally shrank from eleven to three, namely China Communications Construction Company, China Railway

Construction Corporation, and China Railway Engineering Corporation. According to the Chinese bidding law, at least three companies are required to participate in the bidding, and if one of them does not join, it will face the situation of failing to be sold at auction.

"*We do not have enough experience, and we have to do that by ourselves. It is a fundamental challenge. Then you will need to do it differently*." (interviewee from the owner)

So the HZMB authority took a different approach to traditional tendering. The HZMB authority director led a team to visit the three major candidates to promote the HZMB project. It was a problem and goal-oriented, in-depth discussion of the design and construction general contracting mode, technical difficulties the HZMB project faced, and how to improve the bidding mechanism, contract mechanism, technology solutions, etc.

Among the three, China Railway Construction Corporation and China Railway Engineering Corporation were not relatively good at marine engineering, and China Communications Construction Company was the largest in the global offshore market. The HZMB Authority adopted two approaches. Firstly, they encouraged bidding candidates to integrate industrial resources. Three candidates quickly took action to speed up mergers and acquisitions on the one hand, and accelerated cooperation with overseas first-class offshore enterprises, and established the auxiliary port and shipping bureau on the other hand. It was allowed to use construction consulting services and equipment leasing to make up for offshore construction shortcomings. The purpose was to create equal conditions and enhance competitiveness for all bidders on the same starting line. This has achieved a good result. Secondly, considering the risk that companies would not invest in the bidding stage, the HZMB authority applied to the three governments for a special fund for bidding compensation, which was 6 million, 4 million, and 2 million RMB, respectively, which can partially cover the cost of the bid preparation. At the same time, potential candidates were provided with many project planning materials, including the latest planning documents. Several top-ranking candidates were mobilized with enthusiasm and technical strength. They also put forward some constructive opinions and suggestions on risk control. As a contribution to knowledge achievement, they later served the overall goal of accomplishing the HZMB project.

7.4.3 Learning by collaboration

The Hong Kong side led the HZMB's preliminary work due to its rich and mature experience. Hong Kong is an internationally open market, so the project has been benchmarking globally from the very beginning. This is an example of cooperation between the three regions.

It is necessary to fully absorb and learn from the experience of similar projects globally to attract global professional, experienced organizations to participate in the HZMB project. The purpose is to control risks, improve quality, and ensure the smooth implementation of the project. In the HZMB project, a

joint venture for a design and build general contract was adopted, and collaboration was undertaken with large networks of market actors.

The partnership is the philosophy pursued by the HZMB Authority. It requires the cooperation of all parties to solve problems around the target. The life cycle design and construction consulting services, including special consulting services, were adopted directly for the owner. From the planning and design to the construction stage, from designer and contractors to construction quality consultants, the international characteristics of HZMB participants are outstanding. The teams participating in the HZMB came from all over the world, including the United States, United Kingdom, Germany, the Netherlands, Denmark, and Japan. Twelve overseas enterprises cooperated with the HZMB Authority, with a total contract price of nearly 300 million RMB. To meet the relevant provisions of domestic laws and regulations and to effectively introduce external professional resources, the HZMB authority adopted a Sino-International cooperation joint model: 1) COWI A/S (Denmark) and ARUP (the UK) participated in the design of immersed tunnels and steel bridge girder box. 2) Chodai (Japan) and Halcrow (the UK) joined the design of the steel box beam structure and steel-concrete composite beam structure. 3) Anderson Asphalt (Hong Kong) attended the deck pavement design stage. 4) TEC (the Netherlands) and TY Lin International Group (China) were introduced to the immersed tunnel and bridge consulting team. 5) Mott MacDonald was hired as a life cycle quality management consultant. More companies were added to cross-check the design and construction quality. For example, 6) AECOM (the United States), COWI A/S (Denmark), NCC (Japan) joined in the island tunnel engineering design and construction. 7) Aeschlimann AG (Germany) participated in the bridge deck pavement construction. The close collaboration was verified mutually by interviewees from the owner and consultants:

“TEC from the Netherlands is the undertaker of design and construction consultation on the immersed tunnel and artificial islands for the life cycle of HZMB. I had numerous conversations with the head of the consulting firm.” (interviewee from the owner)

"Monthly or at the key design or construction implementation time, I would come to the site of HZMB. I had face-to-face communication with the person in charge of the project planning and contract, on project management, and immersed tunnel technology almost whenever I came to Zhuhai." (interviewee from the consultant)

It is agreed in the focus group discussion that in this context of the deep involvement of international resources and high concentration of the domestic best quality resources, the HZMB authority established the "best partnership," which is extremely rare in previous Chinese domestic projects. A quote from an international consultant better stated this: “*I am enthusiastic about the HZMB. Yes, I very much enjoy being a part of this*.”

The participation of a big international supporting group is constructive. The most important thing is to provide support for systemic risk control and provide optimization and monitoring in detail design and manufacturing processes and overall project management. The HZMB project is filled with independent innovations and the active introduction of international resources "*for my use*." There are only about 100 people in the HZMB Authority. The HZMB authority invited the most experienced international organizations to help them with better control. They are "gatekeepers" and play an essential role in the field of risk prevention and control. Besides, these international partners have also brought new management ideas and new technologies.

7.4.4 Learning by external resources

In the planning and design stage, plenty of learning action episodes are found. With little experience in offshore megaprojects, the HZMB Authority visited the US, Japan, South Korea, Denmark, and Sweden on study tours to get inspiration of how reference projects (e.g., immersed tunnels) had been conducted, especially the existing strait passages, such as the Öresund Channel between Sweden and Denmark (completed in May 2000) and the Busan Geoje Channel in South Korea (completed in 2010). It was found that all of these projects adopted the mode of general contracting, which inspired HZMB to use the same. The project delivery of HZMB benefited from other similar projects. A great deal of the knowledge and experience was transferred. This has put HZMB at the forefront of research and developments in the relatively proven technology, which improved the solution and decreased risks later on.

As some standards, specifications, and technologies were unavailable, HZMB team members often relied on mature international ones. The HZMB authority organized design, consulting consortiums, and scientific research organizations to collect relevant existing specifications. They analyzed and compared the applicability of the specifications and proposed standardized use of requirements according to specific design contents and project characteristics. A complete HZMB project technical standard system was gradually established, covering all aspects of design, construction, and operation. Among them, 1) the design life of HZMB adopts the British standard of 120 years; 2) the concrete technical index adopts the highest standard from Europe; 3) the lane width adopts the Mainland China standard of 3.75 m; 4) the emergency lane width adopts the Hong Kong standard of 3.1 m. Regarding the quality management system, reference was made to the product certification systems for concrete production in Hong Kong, Macao, and high-speed rail construction in Mainland China. An interviewee from the HZMB authority explained, "*We cannot just copy and paste. What we can do is to learn from the world and do it for the project.*"

7.4.5 Learning by experiment

Most of the interviewees shared challenging situations during the HZMB project. They contended that

these challenging situations and experiments that tried to solve the problems could be learning opportunities.

A learning action episode was provided in the focus group discussion to explore how manufacturing concepts can be applied. Effective use has been made of large precast and prefabricated elements to minimize disturbance to marine life and achieve quality and construction speed. Pile caps, steel bridge decks, and steel towers were manufactured off-site and transported to the construction site for erection. The tunnel sections were precast at the yard on Guishan Island and transported by tugboats to the construction site for placement in their final position. Prefabricated steel structures were adopted to reduce the difficulty to work under deep water conditions and shortened the construction time.

Another learning action episode is about the integral erection method for erecting the channel bridge's steel tower. There were numerous challenges, including the water current, wind speed, and existing navigation channel's operation. This method could substantially reduce the on-site welding work and enhance the quality of steelworks during the construction. Site trials were carried out to ensure the safety and quality of practices before the erection of steel towers. The adaptation of inter-industry knowledge could be a crucial element to explorative learning.

An example illustrating the experiment was the towing and immersion of the tunnel sections in the open sea. A standard tunnel section immersed pipe weighed about 80,000 tons, similar to an aircraft carrier. The sections were towed through the busiest area of the Lindingyang Sea, where more than 4000 ships come and go every day. Strong and unstable wind speed, water current conditions, airport height restriction, working under deep water, and tight tolerance of connection within ±25mm had to be overcome when tunnel sections were placed. As a result, controlling a section during the towing process was a significant challenge. Eight high horsepower propeller tugboats were used to tow a section when scientific forecasting techniques predicted suitable weather and hydrological conditions.

Moreover, the contractor developed the first immersion pontoons in China to be equipped with comprehensive operating and control systems. By applying remote control and information technology, the two pontoons could adjust the position and control the section's axis and achieve a precise connection. After 96 hours of uninterrupted transportation and installation, the first tunnel section was docked with the western artificial island on May 6, 2013. In 2014, the tunnel sections were installed as deep as 46 m below sea level. The contractor deployed the largest lifting barge in the world to erect and install the final connection. In 2015, the E15 tunnel section encountered the severe challenge of exceptional siltation. After two unsuccessful towing and immersion and the Guangzhou government's support, tunnel section E15 finally achieved a precise connection on March 26, 2015. This played an exemplary role in the following tunnel immersion project. Workers were deployed to perform welding and grouting works inside the tunnel sections immediately after tunnel sections E29 and 30 were connected. On

March 7, 2017, the last tunnel section was put in place successfully, and a closure joint was installed on May 2.

HZMB was an international infrastructure development project. The HZMB authority had a global vision and cross-domain thinking. They actively introduced management concepts and technologies from international markets while focusing on independent innovation through cross-industry and cross-disciplinary learning and reference. The project was managed partly through original innovation, partly through introduction, absorption, and re-innovation.

7.5 Discussion

Our research has found that explorative learning can be at the heart of learning action episodes. Emerging from the data, we identify four strategies (owner leadership, collaboration, external resources, and experiment) that enable explorative learning. They can significantly augment the learning process. The four strategies are characterized as information-rich and useful in dealing with high levels of ambiguities and uncertainties in the megaproject.

7.5.1 Reflection on megaproject complexity

As an infrastructure development megaproject, there are some inherent new characteristics in the HZMB project. The construction methods have more transitioned from the traditional site-construction methods to prefabricated production and rapid manufacturing approaches. The megaproject's complexity asks to bring in more new project participants like special equipment and material suppliers, immersed tunnel design and construction consultancy, and so on. Finally, there are many first encountered situations in this megaproject due to the complex environmental conditions and three separate legal systems and technical standards (Mainland China, Hong Kong, and Macau). There are no similar lessons learned in the past.

Megaprojects are seen as voyages of discovery (Chudson and Hirschman, 2006), which depend on creativity and innovation while underway to achieve project goals. Bakker et al. (2011) discuss the project learning paradox: the autonomy of projects brings opportunities for creating new knowledge, but results in the difficulty of disseminating this knowledge precisely. The uniqueness of the task and the project's complexity can lead to learning (Burke and Morley, 2016; Tatikonda and Rosenthal, 2000). Innovative projects are characterized by a high level of ambiguities and uncertainties, and the usefulness of traditional knowledge management tools might be severely lessened. The more unique the tasks faced by project members, the less prior experience they can use, and they have to conduct exploration, which makes the execution of the task unpredictable. Uncertain environments offer more scope for learning in complex projects (Cooke-Davies et al., 2007). This makes them much more challenging to manage, and equally, much more interesting to research.

HZMB has been delivered successfully, and the project we observed exhibited explorative learning. Results show that explorative learning is used to explore new engineering technology and management knowledge. The results revealed that exploration has shaped the learning process in the infrastructure development megaproject and has further affected the evolution and operation across various project development stages. The efficient integration of learning could improve design and construction performance. It is critical to recognize the complexity and navigate it, be aware of the inevitable criticalities and threats, and develop distinctive organizational capabilities for continuously driving complexity factors.

In summary, many of the organizational factors potentially influential to explorative learning are likely to become more prominent with scale and complexity. The case project is technically very complex and pushing organizational boundaries. This drives higher levels of explorative learning.

7.5.2 Relationship of key learning strategies

Because the megaproject has an unusually long supply chain with a very complicated and diverse manufacturing and construction sections, it will undoubtedly stimulate explorative learning. The learning opportunities are extraordinarily significant. Our case study demonstrates the importance of offering a better understanding of different kinds of explorative learning strategies and how they gradually unfold to shape the project's progress. Explorative learning is formed by the interplay between four strategies of leadership, collaboration, external resources, and experiment. Their relationship has been mapped out in **Figure 7.3**. The project’s reaction to learning depends on the inter-relationship. One bidirectional arrow to and from learning strategies indicates that there is mutual interaction. These elements are analytically distinct. They will collectively influence the project.

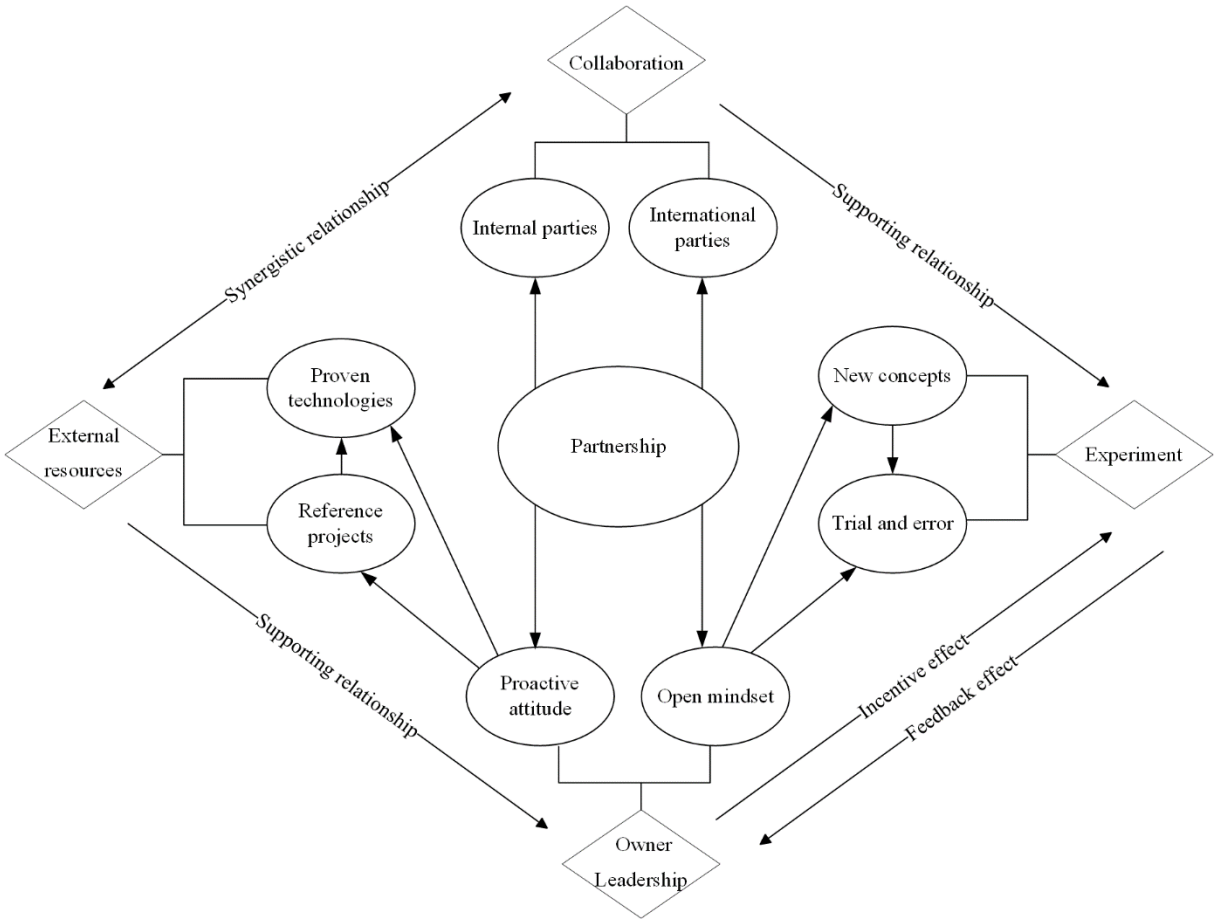

Figure 7.3 Relationship of key learning strategies

Such exploration requires a fundamental shift in organizational design and a break with prior project routines and capabilities (Davies and Brady, 2016). It involves establishing a vanguard project to investigate the new opportunities, encourage creative problem solving, and efforts to establish new project routines. This includes experiential search processes, real-time learning, and the pursuit of multiple solutions until the best one can be selected (Klein and Meckling, 1958; Lenfle, 2008; Nightingale and Brady, 2011).

7.5.2.1 Owner leadership as the driver

Decision-making, planning, and project management are typically multi-actor processes involving multiple stakeholders with conflicting interests in the megaproject. Often, projects are led by planners and senior managers without deep domain experience throughout the lengthy project cycles, leaving project leadership weak (Flyvbjerg, 2014). They may sufficiently drive their own actions, but not enough to motivate others, which is not beneficial for inter-organizational learning. Extant literature has underlined that in multi-firm collaborative settings, of which megaprojects are a noteworthy example, particular organizations play a fundamental role as lead innovators (Baldwin and von Hippel, 2011). Our research provides more insights into the owner's role, as summarized by an HZMB authority

manager, that "*the owner's thinking determines the project's success or failure. The contractor's conduct determines the quality of the project. The composition of the project team and the stakeholders determine the reputation of the project.*"

Respondents in our research indicate that they experience the owner's proactive attitude and open mindset quite heavily. The owner sets the tone, breaks the ice, and takes a pivotal role in driving learning. Bakker et al. (2011) determined that the project parent organization's responsibility is to ensure that knowledge was valued and utilized, not the project manager. A high level of absorptive capacity was required for success. Davies et al. (2009) demonstrated how system integrators search for improving megaproject performance by carrying out innovations according to the rule of "recombination" and "replication" of a system of production processes. A strong owner made a significant contribution to absorbing lessons learned from reference projects and best practices from proven technologies, bringing internal and international professions together, stimulating them to share experience and lessons learned with each other, and finally improving the project performance (Winch and Leiringer, 2016).

Construction has tended to treat errors as being problematic and a source of failure rather than a road to eventual success and source of innovation (Love et al., 2013). Breakthrough innovation is often avoided because it often creates uncertainty and increases infrastructure project costs (Van Marrewijk et al., 2008). The inherent issue has become ingrained within project-related practices, focusing on error prevention, and relying on existing technologies and established routines (Love et al., 2019). A number of innovations were implemented in this case. All these innovations did not go smoothly, but they will not come into being at all without the owner's open mind. Errors, however, do not necessarily have negative consequences. The project development is dependent upon doing something new, making errors, and then trying to improve. Dealing repeatedly with experiments and optimizing the positive consequences can lead to further problems being resolved and therefore contribute to its progression and maturity (Frese and Keith, 2015). Explorative learning optimizes the positive consequences of new concepts and errors.

7.5.2.2 Mutual relationship between collaboration and external resources

We show that learning cannot be segregated from the partnership. The HZMB project's case addresses how internal project partners and international networks are aligned to drive and disseminate innovation.

The cross-border feature also provided us another insight into management issues due to the three different political systems involved (Qiu et al., 2019). HZMB is the first mega infrastructure development project built jointly by the three governments of Mainland China, Hong Kong, and Macao with different legal systems and technical standards. Each of these three regions had its own administrative rules and procedures for the significant processes of project management issues. The basis of the project is collaboration and partnership.

The owner brings all parties together to form complementary competencies, especially the international pioneers, which is one of the most influential and efficient ways to facilitate innovation and knowledge sharing among like-minded individuals and introduce new members into the organization. This is echoed by the importance of adopting a community-based approach to managing knowledge in project settings (Bresnen et al., 2003). Inter-organizational collaboration is vital for explorative learning (Parida et al., 2017; Shenhar et al., 2016). Exploration is enhanced by various teams in which individuals have different experiences and affiliations (Andriopoulos and Lewis, 2010; Eriksson, 2013; Lavie and Rosenkopf, 2006), which is reflected in the form of an international supporting group in the HZMB case. Their sharing of their local and tacit know-how is essential for sound decision-making.

As high levels of ambiguity and uncertainty exist, one approach is to replicate previous projects and proven technologies/standards. The project management team should learn about best practices in different locations to improve outcomes. This allowed for assessing what has worked before (Davies et al., 2017) and inter-project learning (Brady and Davies, 2004; Prencipe and Tell, 2001).

Therefore, the proactive owner attitude drives better collaboration across project stakeholders and take an open mindset to look for abundant external resources from the market. The combination of collaboration and external resources brings more approaches in parallel for actors to pursue. The project has the opportunity to observe what approach does work and what does not work so that the appropriate approach can be selected under high uncertainty (Lenfle and Loch, 2017).

7.5.2.3 Experiment as an acceptable process

Traditional systems engineering tells us to identify as many risks as possible in the preliminary design to reduce the cost of errors. There are established routinized learning practices in permanent organizations. Learning speed tends to be slower than in megaprojects, as there is less sense of urgency (Hobday, 2000; Prencipe and Tell, 2001; Sergeeva and Roehrich, 2018). Megaprojects can be seen as experimental learning processes (Lenfle, 2008; Sommer et al., 2009). The production philosophy learned from other industries, especially manufacturing, was thought of as worth exploring (e.g., Koskela 1992; Egan 1998). The HZMB project explored how manufacturing concepts can be applied to the construction context to improve productivity. The research shows that in a megaproject with new assignments and vital innovation components, the first projects are innovation-driven and, therefore, at the forefront. They are the vanguard project. The goals are often achieved by learning through trial-and-error experience. An application, tool, or idea applied for the first time can be further explored and ultimately lead to a routine that can be used. The megaproject innovations are developed in such a way that they lead to more routine work and more efficiency. The developments within a project are at the megaproject's service and can be shared in a broader context. There must be and remain space for mistakes, development, and variation. Innovative solutions most frequently stem from adapting to tasks that turn out to be more challenging than initially expected.

Furthermore, innovation is an unattainable goal without performing experiments and making errors; the discovery processes are inherently contradictory and chaotic and naturally subject to error-prone (Bledow et al., 2009). Punishing failure chokes innovation. In the HZMB project, project teams must put in place mechanisms to report, share, communicate, assist with, and handle errors that arise in projects quickly. Mistakes made in one section will then be made less or not at all in subsequent sections, and smart solutions can be applied immediately and further developed in the following projects. Establishing a vanguard project and then gradually developing the routines contributes to achieving economies of repetition in the new category of the project (Brady and Davies, 2004; Davies and Brady, 2000). Rehearsal first can help identify risks and explore options (Davies et al., 2017). It is an iterative process of producing new knowledge through experiments, trials, and feedback. The owner is sharing the risk with partners as collaborative project participants and innovatively using external resources. This saves time and ensures recognizable uniform projects. This echoes the trial-and-error learning action (Lenfle, 2016; Lenfle and Loch, 2017), which argued that failure is a source of learning, and experimentation plays a central role in megaprojects.

7.6 Conclusion

This research applies the learning perspective to explore how megaprojects construct their identities as learning organizations. The megaproject is a system of systems. Engineers tend to focus on reducing complexity but increasing complexity might bring value with more significant learning opportunities. Our research sets out to explore the emergence and role of explorative learning in the megaproject. On the one hand, it is the hope that the project itself will succeed. On the other hand, the project will enhance the technology level and catch up with the technological trend so that the exploration can drive the primary project team and keep in line with the industry's frontiers. We emphasized the more dynamic learning focused on the innovative changes within megaprojects. The examples of learning action episodes in HZMB are reported, and explorative learning strategies in megaprojects are sought. This research explains how explorative learning is enacted by owner leadership, collaboration, external resources and experiment, and their relationship. From the macro level, explorative learning is supported by the intensive collaboration and effective use of external resources. From the micro-level, there is spontaneous problem-oriented experiment learning. The owner's leadership drives all these. These strategies jump out of traditional project planning and controlling mindset and fit with the logic of entrepreneurial orientation, in line with the research stream on the management of exploration projects (Brady and Davies, 2004; Frederiksen and Davies, 2008; Lenfle, 2016, 2014, 2008). This is exploratory, interpretive research to understand linkages between explorative learning and megaprojects, ultimately inform researchers and practitioners in managing innovative projects and project-based learning in the future.

7.6.1 Theoretical value

The megaproject is so complex that a single partner cannot solve all problems and look ahead in the future alone. Prior research has highlighted the importance of simultaneous explorative and exploitative learning within and across projects. The research tentatively explores the learning in an infrastructure development megaproject, the world's longest cross-sea bridge, HZMB, and analyses the practical and explicit benefits of taking advantage of new and existing knowledge.

Megaprojects can be treated as organic phenomena (rather than static engineering artifacts) (Dimitriou et al., 2013). In the past, project management was seen as a card-playing game in a closed system. That is why we pay much attention to the iron triangle. This applies in simple projects that address predictable and repetitive tasks while not in novel projects organized to deal with unforeseen uncertainties (Loch et al., 2011). Large complex megaprojects are becoming more innovative. Extant knowledge cannot satisfy the requirements of the project. The research of megaprojects offers an alternative to the conventional firm-centric view on innovation.

The value of conceptualizing explorative learning at the project level is demonstrated in the research. Our case study illustrates that several strategies jointly shape the major learning action episodes and that these strategies build on each other. Prior concepts are confirmed, such as transformational leadership (Jansen et al., 2009), collaborative innovation (Baldwin and von Hippel, 2011), external learning capabilities (Bierly III et al., 2009), and trial-and-error learning action (Lenfle, 2016; Lenfle and Loch, 2017). For researchers, we contribute to the emerging literature on project-based learning with a megaproject perspective.

7.6.2 Practical implications

Large and complex megaprojects are characterized by uncertainty and ambiguity. Project participants can take projects as an opportunity to implement novel design ideas with innovative construction methods and management. It is essential that learning occurs. This is also in line with rules for managing complex megaprojects (Davies et al., 2017). Project managers should be aware of the learning in megaprojects and adapt their learning behaviors to brace the project complexity. There is a strategic role in exploration. We propose that public entities need to be more proactive in the support they provide for these megaprojects. Infrastructure megaproject managers must proactively absorb external knowledge resources and strengthen their expertise and develop flexible learning capabilities. It is instigated to think of partnering arrangements like pain and gain share to identify what behaviors would ideally be encouraged. The project must engender a learning culture and communicate learning, where trial and error is a likely eventuality. Actors, especially international contractors and engineering consultancies, will benefit from understanding the logic of explorative learning. The best practices from the HZMB project will provide valuable experience for the future cross-border Belt and Road initiative projects and

the Shenzhen-Zhongshan link.

7.6.3 Research limitations and future work

The case of the HZMB project might cause some bias. While the research was conducted in the Chinese context, it is suggested that the findings presented would align with the experiences of construction organizations in other parts of the world. Naturally, cultural nuances would need to be considered. A conclusion based on one case is not very sound and valid. There are limits as to how far the findings based on a single case study can be generalized. To generalize conclusions to the learning process in infrastructure development megaprojects in general, probably surveys are required among various organizations.

Megaprojects would illustrate a higher propensity towards explorative learning, as procedural controls and limited autonomy prevent disruptive activities that require explorative learning. The level of explorative learning is influenced directly by the organizational structure. Further research assessing explorative learning as a comparative case between a traditional organization and a program-based organization consisting of largely autonomous projects would be of great interest.

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Chapter 8 Facilitating Learning in and from Infrastructure Development Projects: a Cross-case Analysis

Abstract

Over the last decades of development of knowledge management and organizational learning, there has been an increase in the study of project-based learning. We address this topic in the context of infrastructure development projects. Through pilot case studies carried out in the MultiWaterWork program and Gaasperdammer tunnel project, both in the Netherlands and Hong Kong–Zhuhai–Macau Bridge in China, the empirical investigation uses a cross-case analysis and presents reflections. We show how learning is unfolded in three different cases and bring the three cases together. The empirical evidence gathered in this research forms five project-based learning principles: 1) Owner commitment, 2) Social environment approach, 3) Collaboration vision, 4) Value orientation, and 5) Open mindset. The study then focuses on the contribution of learning to achieve project capabilities. It is suggested that the critical role of learning in developing project capabilities should be on the future research agenda of infrastructure development projects.

Keywords: Project-based learning; capabilities; cross-case analysis; infrastructure development

The previous version was presented in the Project Management Congress (April 2019, Delft the Netherlands).

8.1 Introduction

In the project environment, learning from successful and unsuccessful projects enables project participants to make decisions and solve problems for staying profitable and competitive. Knowledge represents a strategic asset that can result in more internal effective business processes and a more apparent competitive advantage in the market (Wiig, 1997). Best practices and lessons learned bring fresh ideas and new approaches and enable project participants to address new and more complicated issues more effectively and efficiently than ever before. However, learning and reusing knowledge is still challenging (Wasko and Faraj, 2005), often hampered by professional or organizational boundaries or contractual concerns. The construction industry's conservative culture leads to the belief that every construction project should be considered unique (Kwofie et al., 2014), overlooking some forms of repetition found in every project. Project knowledge has a high degree of reliance on the situational context and the adopted project processes (Bresnen et al., 2003). The ultimate goal of the client is that the project should meet customer expectations and make profits. This definite goal limits project participants' attention to accumulate and transfer knowledge, resulting in "project forgetting" that the knowledge and experience generated in a project life cycle are lost at the end of the project. The theory of organizational learning cannot be directly transferred to project studies as the debate on project uniqueness and temporality hinders its applicability (Koskinen, 2012). Hence, learning from past experience and stopping re-inventing the wheel in the follow-up projects is missed.

This research sets the following research question: “How can learning be promoted in large infrastructure development projects?” We address this question by reporting on an empirical investigation of three case studies in an effort to promote learning in and from projects in the context of infrastructure development. This empirical investigation explores a repeatable and agreed understanding of project-based learning into some good practices. It arrives at how identification of principles can improve the learning performance in the project setting. Finally, we reflect on findings and call for learning theories to facilitate learning in infrastructure development projects.

8.2 Methods

The research chose the cross-case analysis of three cases to seek more general results and a deeper understanding of large infrastructure projects' learning processes. Cross-case analysis can mobilize the knowledge from individual case studies and support the creation of clusters of phenomena (Eisenhardt, 1989; Yin, 1983). The previous three chapters have reported on three single case studies.

A mixture of ongoing and retrospective case studies was used to obtain rich research data and a complete image of the infrastructure development projects' lifecycle. **Table 8.1** provides a summary description of each case. Among the three cases, the project MWW was just beginning; project GSP was halfway through the execution phase, the project HZMB was delivered recently. Collective learning takes place at different levels in project-oriented organizations: learning by the parent organization from projects (meta-project learning), learning within projects (intra-project learning), and learning between projects (inter-project learning) (De Groot et al., 2020). The three cases cover all mechanisms of project-based learning (see **Table 8.1**). They have covered all elements involved in the process of project-based learning (see **Figure 8.1**).

Table 8.1 Summary of three cases

Case (and abbreviations)	Description of the project	Locus of the project-based learning	Type of learning
The MultiWaterWork program (MWW)	A large program for the replacement and renovation of 52 ship locks over the next 30 years in the Netherlands	To mobilize expertise from the market and knowledge partners to create resilient locks adaptive to future technical, economic, and environmental developments	Meta-project learning
The Gaasperdammer tunnel (GSP)	The longest tunnel project on land in the Netherlands	To have a constant reflection going on in the project rather than just learn from the project after it has finished	Intra-project learning
The Hong Kong–Zhuhai–Macau Bridge (HZMB)	The longest sea-crossing linking Mainland China, Hong Kong, and Macau all over the world, in the form of a bridge structure, an immersed tunnel,	To adopt advanced technologies and management philosophies to address the project complexity and satisfy the innovation requirements	Inter-project learning

and two artificial islands

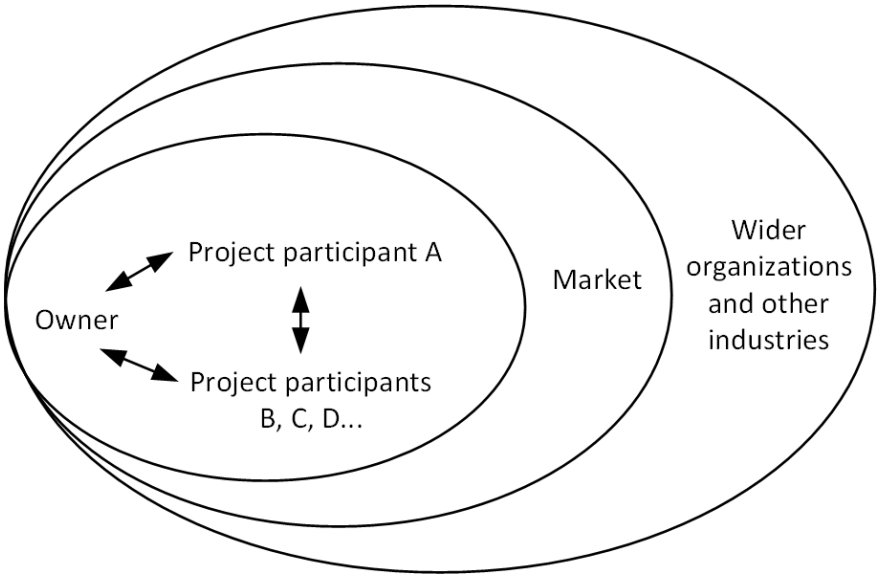

Figure 8.1 Levels of project-based learning

8.3 Findings

All three cases are perceived as successful during the implementation of project-based learning. While there are different cultural environments and development processes to delineate cases, there are the following commonalities. The inductive cross-case analysis was employed to identify common conditions from the data. Many conditions need to be in place to facilitate or enable learning in projects or between projects. Five conditions emerged across all three cases regarding Leadership, Environment, Relationship, Perceptions of knowledge, and Perceptions of the way of thinking. The following sub-sections provide information on how cases could create and manage the conditions.

8.3.1 Leadership

In all cases, we found that each project participant holds a partial and limited vision of the project and its learning objectives. For instance, in the MWW case, the market partners came to the co-creation sessions with a double agenda of collaborating and looking for new work assignments. These may sufficiently drive their own actions, but are not enough to motivate

others, which is not beneficial for inter-organizational learning within the project. A particular group of experts or stakeholders cannot learn on behalf of all stakeholders (Pahl-wostl et al., 2017).

In order to ensure that knowledge is well spread, leadership is needed. The owner sets the tone, breaks the ice, and takes a pivotal role in driving learning. Bakker et al. (2011) determined that it is the responsibility of the project parent organization to ensure that knowledge is valued and utilized, not the project manager. In Case MWW, the owner proactively advocates value co-creation with all potential market partners and knowledge partners. In Case GSP, the alliance name RIXWAS, an intertwining of IXAS and RWS, was created showcasing the relationship between the owner and contractor. In Case HZMB, the partnership is the philosophy pursued by the HZMB Authority. The owner requires the cooperation of all parties to solve problems around the target.

Unlike the manufacturing setting, clients in infrastructure development projects are generally highly motivated to interact with the professionals because the core of professional services is to address their needs. The owner aiming to exert the governance of knowledge and act as the learning organization integrator should recognize the central and influential role in putting effective learning on the agenda and maintaining it throughout the project. The owner's project learning impact can be extended from the early planning to later operation stages. Still, the learning of project-based enterprises is mainly to achieve economies of scale. The cycle of experience accumulation, knowledge articulation, and knowledge codification (Prencipe and Tell, 2001) requires senior leadership intervention in making the necessary mediating policies and cultures.

In all three cases, the owner is mainly responsible for establishing the culture, and all parties should maintain the culture. In the GSP case contract, the owner provided a provision for regular alignment sessions in which the client and contractor exchanged views on specific topics. There is a clear incentive to improve knowledge sharing between the different parties.

In summary, the knowledge-sharing behaviors depend on the owner to be active, committed, and engaged. This supports Winch and Leiringer's (2016) argument that the strong owner is

discussed in the context where the owner is reduced to a client as a mere contract-giver. In this sense, the owner's attitudes and actions shape the project participants' knowledge sharing behaviors and influence how they learn and adapt it (Lekkakos and Robertson, 2009).

8.3.2 Environment

It is difficult to quantify what type of knowledge can be shared in the learning process. "Soft" knowledge manifests itself as something more relevant in our cases. Know-how and know-who are more "tacit knowledge" and are more difficult to codify and measure (Lundvall and Johnson, 1994). One of the main aims to organize four co-creation sessions in the MWW case is to reduce the social distance between stakeholders. In the case of GSP, an exploitative learning trajectory program has been set up in collaboration between the owner and the contractor to provide a space for open dialogue, and this was generally experienced positively. Profound learning happens when people share their experiences, ask open questions, and tell honest stories. The prerequisite for learning is not processes, tools, or artifacts, but establishing the cultural and social environment: reflecting past experience, trusting partners, and communicating openly to ensure a stringent process for decision-making and problem solving (McClory et al., 2017).

Learning is seen as a people-oriented strategy. Project knowledge produces and displays the narrative characteristics. In practice, project managers focus on project context and complexity and give a detailed narrative and analysis of the case. People with different backgrounds can provide different interpretations of objects with varying contexts. In this process, project participants and their interactions have a situational interpretation by social conditions. In Case MWW, market partners and the owner require valuable but different knowledge: owner experience, market experience, and scientific research. Complementary knowledge can develop program themes that satisfy evolving local demands and lead to new work practices.

There is a big learning curve between projects. Projects often have short-term goals, while knowledge management aims in the long term. Projects as temporary forms of organization have particular characteristics that determine challenges for knowledge management (Lindner and Wald, 2011). The learning concern is getting and sustaining attention. The social environment can create conditions for communicating and sharing knowledge. In the social

environment, project participants overcome the limitations of conventional hierarchical forms. The HZMB project does not have the ambition to build a knowledge system. There is less need to record the knowledge in systems for the rest of the standing organization. The megaproject opts for active knowledge transfer to and within the target project team. This means that knowledge remains with the people, and a limited number of documents is produced when the project ends.

8.3.3 Relationship

We each have a "learning horizon," a breadth of vision in time and space within which we learn effectively. When our actions have consequences beyond our learning horizon, it becomes impossible to learn from direct experience (Senge, 1990). It is clear to recognize that project participants should learn from various parties, share and transfer knowledge between organizations and projects.

The industry is eager to collaborate, but the industry has trouble identifying partners to collaborate with and extract value from those collaborations. In the past of cases MWW and GSP, the owner determined the scope, and it was up to the market to solve it. In new situations, the owner does not know how to do things right, and the market does not know how to do the right things. More bonding is needed to be created between public and private. This brings “collaborate to learn” and “learn to collaborate” on the agenda.

Collaboration is a valuable learning strategy because it provides the project-based organization with access to new human and intellectual resources (one dimension of value identified in the co-creation sessions in the MWW case) and brings knowledge together and improves performance. Many interviewed project managers explained that collaboration, particularly in the supply chain, is more important than mutual concealment. As the interviews demonstrated, “who cannot share, cannot multiply"; "differences in perspectives can be helpful, once recognized!" Project participants can leverage their capabilities over time in successive projects because there is a learning effect that translates past experience into adaptability and moving faster and more effectively in new settings.

All three cases recognized collaboration as the most crucial issue during the learning process. The owner and contractor tried to implement a move away from the traditional way of thinking, which may be seen as adversarial towards a more collaborative culture. Collaboration is about learning and creating value by working together. The partnership is a direct result of this shared project culture, as in practice, this collaboration was experienced as very open and friendly. The culture of the owner in Case GSP and Case HZMB has been conceptualized as an alliance culture. This refers to a culture in which working together is the norm. During this collaboration, there were lessons learned from each other as well, and this line of thought fits with the learning process. In Case MWW, both the owner and the market partners argued that the exchange of knowledge should be outside of the contract. There is also a clear incentive to improve the knowledge sharing between the different parties in the GSP contract.

8.3.4 Perceptions of knowledge

Learning is a value-improving practice recognized by Construction Industry Institute (CII) and Independent Project Analysis (IPA). Project-based learning is not just a momentary achievement, such as the successful transfer of knowledge as a product, but a continuous performance in which learning is a daily process. Conventional knowledge management holds the management logic, aiming to keep the project within critical parameters such as schedule and cost. We noticed that the service logic of solving a specific client's specific problem instead of the management logic of keeping the project on track becomes the prime logic in our cases. The MWW case study has found three contributions of co-creation sessions for creating value at the front end. Co-creation sessions help clients and market partners to communicate about and improve value propositions before a formal contract bounds them. Central to these sessions is knowledge exchange, discussions of earlier experiences with similar projects, and open discussion between stakeholders to identify adaptive solutions and supplement and strengthen the value propositions addressed in programs. Value-oriented learning is essential because it gives people a sense of ownership. This condition is concluded in the case of MWW. We can substantiate and even expand it by combining new information from the cases GSP and HZMB.

Conventionally, knowledge was seen as objects. In our three cases, the experience that was

learned by the interviewees was not only practical but somewhat more bound to "soft" knowledge. In this sense, the temporality of expertise generated in projects does not play a significant factor in its assimilation possibilities. Instead of reducing the cost and shortening the projects' schedule, it may be more important to think about the value delivered by learning to improve the whole performance and organizational capabilities. Project participants were interested in value creation mechanisms. People believed in a broader interest and did not put their own short business interests first. Everyone has a new understanding of the challenges they are facing. Differences of opinions are valued and sublimated, and a new consensus began to take shape.

Learning gives meaning to what is happening in the project. In that sense, it is also the carrier of the culture in an organization. All project participants have situational considerations and the sub-cultural context in the project environment. Both the owner and contractor in Case GSP stand closer to each other than they do to their parent organizations. The collaboration was predominantly positive and personal; this only exemplifies the shared project culture and the mindset that would be brought to the next project. This project culture was experienced strongly, even more so than separate organizational cultures. The concluding remarks seek to establish a relationship between organizational culture and learning environment to motivate employees to communicate and share knowledge and expertise with their colleagues and across the supply chain instead of working in "silos."

8.3.5 Perceptions of the way of thinking

It is difficult to quantify what type of knowledge can be shared in the learning process. Soft knowledge is something more relevant in our cases. In Case GSP, the most significant change that the learning trajectory has led to is the mindset shift. The learning trajectory can be conceptualized as thinking and discussing more things and new things.

Projects undertaken by temporary inter-organizational teams may hinder knowledge sharing and transfer (Bakker et al., 2011b, 2011a; Papadonikolaki et al., 2019). So, we have to go beyond the current needs to include the future usage context, preparing the execution, and keeping looking outside. The position of knowledge management and learning is more than a

best practice toolkit for immediate use. Case HZMB offers new procurement and delivery models to emulate, but not a one-size-fits-all approach. As pioneering megaproject, HZMB has also shown that learning from best practices developed in other industries and innovations such as large precast and prefabricated elements, remote control, and information technology can improve project performance and productivity substantially (Davies et al. 2009; Davies and Mackenzie 2014). Each project has unique challenges and structures. New ideas, practices, knowledge, and tools circulate between projects. It needs not to become a one-stop-shop that has all the capabilities in-house. Instead, it is more a case of knowing what type or scope of capabilities they may need on projects, knowing how it can be developed, and developing the capability skill set.

Learning within projects is a cognitive and experiential undertaking. Edmondson (1999) observed that the better performing teams admit to errors and discuss their occurrence - a climate of openness. Under project-based learning conditions, learning should be diversified to allow mistakes, compliment staff for giving bad news and experimenting with trial and error. In Case HZMB, even though the first few tunnel elements were installed, in 2015 the E15 tunnel element encountered the severe challenge of exceptional siltation. The contractor pooled technical resources to solve the problem. After two unsuccessful towing and immersion attempts, tunnel element E15 finally achieved a precise connection through trial-and-error learning on March 26, 2015. This played an exemplary role in the following tunnel immersion project. For learning to be productive, people must focus on how the project can proceed, rather than blaming someone for a mistake or complaining about a process. People have to be able to speak openly, but with an intention to improve, not to blame and complain.

8.4 Project-based learning principles

The three cases provide interesting guidelines for future infrastructure development project-based learning practices. By examining the underlying conditions enabling project-based learning, we provide principles for effective project-based learning. Principles are smart ways for handling things that happen over and over again in similar situations. All cases provided interesting narrative data and confirmed the importance of five principles for project-based

learning. The five principles for project-based learning are developed as a short, accessible guide. They are:

1) Owner commitment. It calls for the motivation, engagement, and participation of the owner in project-based learning. This principle recognizes the indispensable role of a committed owner as the project champion.

2) Social environment approach. It calls for motivating and engaging teams, facilitating dialogues in social interactions.

3) Collaboration vision. It calls for team members' coordination, quality, and ability to work together to achieve the learning objective.

4) Value orientation. It calls for assigning a more strategic role of learning in the project setting.

5) Open mindset. It highlights the ability of project participants to think outside the box in both project design and implementation.

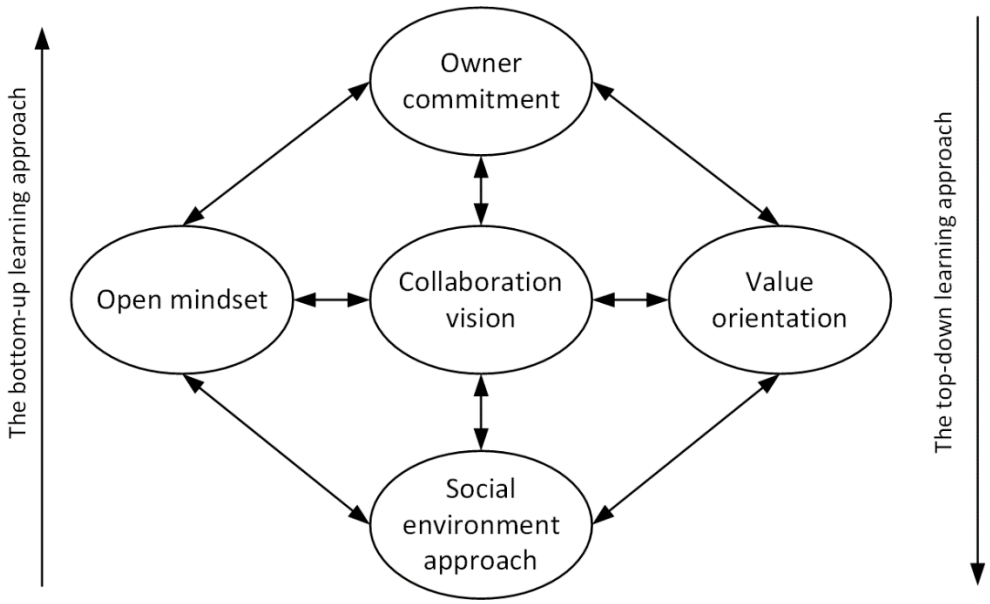

Figure 8.2 Five project-based learning principles

The principles define necessary conditions that have to be met for project participants to learn. They are dynamic and changing and closely related to each other. Due to their synergy and systemic nature, they strengthen each other's effects and are implemented together, not in isolation. The outputs of one principle will provide critical input into another principle, and vice versa. **Figure 8.2** illustrates how projects can use the principles to learn. The arrows between the five principles refer to the necessity of the interrelations. By enhancing each other, principles continually remind us that the whole can exceed the sum of its parts.

The owner often has a better strategic overview of what is needed in the project and can motivate the project team to learn in order to stay ahead. They can make sure that this required knowledge is distributed in the project by, for instance, creating a particular learning program and database. Most of the respondents and interviewees who contributed to the study strongly believed that learning is best achieved through direct interactions with colleagues, other project team members within the focal project or cross-projects, and even outside the organization. The bottom-up learning approach in the social environment helps participants build a narrative that helps tell their story. Project-based learning should be established through social learning processes. The owner commitment principle and social environment approach principle can both facilitate the other three principles. The strong collaborative spirit obtains and maintains the condition by building trust and providing access to information, people, and networks (Ika and Donnelly, 2017). The value orientation principle reminds project participants of the importance of learning instead of only seeking short-term problem solving and performance improvements. The final principle requires us to embrace new ideas even outside our industry, allow mistakes, compliment staff for giving bad news, and experiment with trial and error. Unlike the value orientation principle, which addresses more strategic positioning, this principle addresses learning flexibility, allowing it to evolve to a broader scope. The overview can be found in Table 8.2.

Table 8.2 Use of five project-based learning principles

Principles	How principles can be achieved	Relation to other principles	Application

Owner commitment	Demonstrating learning value; Helping mediate tensions	strengthened	Creating a particular learning program and database; Reward instead of punishment; Proactive engagement
Social environment approach	Creating safe spaces for feedback	enabled	Knowledge sharing workshops; An external knowledge party
Collaboration vision	Generating feelings of partnership	contributed to	Partnership; supply chain management
Value orientation	Attaining consensus and sustainability		Management tool; Shaping the project culture
Open mindset	Thinking out of the box; Allowing mistakes		Innovations from other industries; Experiment

These principles move to a principle-based approach that guides behavior and thinking and describe a meta-capability, not only a process (Eltigani et al., 2020). Typically, a process-based approach, by its nature, focuses too much on predictive work. It is prescriptive by detailing specific actions to be performed and exerting extrinsic motivation. We argue that this type of approach is more suitable for a hierarchical management organization. A principle-based approach should be followed in the context of projects, a flat organizational structure with semi-autonomous operating units. The principles provide boundaries within which to work. The acknowledgment is that there are many ways to remain aligned with the intent of the principles. This is also in line with the incoming seventh edition of the PMBOK Guide (PMI, 2020), moving away from a process-oriented approach to a principles-oriented approach.

8.5 Link project-based learning with project capabilities

The accumulated knowledge in projects might be lost when the project team(s) is(are) disbanded (Bakker et al., 2011a). Project-based organizations lack the natural mechanisms for the knowledge captured in one project to be transferred and reused in subsequent phases and by other projects. There is no copy and paste of knowledge learned in this project to the next project. All three cases agree that the most important lessons learned were, for the most part, bound to the experiences people had during the project and are therefore bound to the people

that experienced them. Learning enables the project team to develop a set of capabilities applied in a dynamic environment. This construct refers to the specific skills and experience required by the project-based organizations to prepare design and execute projects (Eriksson et al., 2017), the high-level management skills and experiences that enable organizations to design deploy projects for strategic purposes.

Construction does innovate in many ways, but much of it is hidden as it happens in practice when problems arise, are solved, and subsequently forgotten. Introducing ideas from outside the project team and learning by doing not only increases the possible sources of innovation, but it also emphasizes a new range of capabilities required to establish and develop weak-tie collaborations (Chesbrough, 2004), manage external proponents of unsolicited changes, allow intellectual property and ideas to flow freely, strengthen problem-solving capabilities, and maintain an overall nimble and proactive organization (Resources, 2011). Project-based organizations that implement large-scale infrastructure development projects need to build capability by understanding their cultural environment and employees' perspectives regarding enablers and inhibitors to knowledge transfer (Davies and Brady, 2000). Project capabilities identify the unique knowledge required to undertake projects tailored to individual customer requirements (Davies and Brady, 2016). Capabilities are developed through integration and transfer of knowledge (Grant, 1996). The firm's ability to move base is dependent on and shaped by previously acquired managerial expertise and experience and its ability to absorb new learning and build new capabilities.

To acquire project capabilities, project participants need to develop and maintain in-house skills, competencies, and abilities to engage with the supply chain. Some capabilities can be seen as the outcome of learning through repeated interactions and will follow different learning trajectories, such as co-creation sessions in Case MWW, the learning program in Case GSP, and the partnership promoted between international participants in Case HZMB.

Researchers argue that dynamic capabilities can be developed through the process of deliberate learning activities (Winter, 2003; Zollo and Winter, 2002). Similarly, Eisenhardt and Martin (2000) identified the experiential learning mechanisms of repeated practice, mistakes, and

pacing of experience. Dodgson (1993), for example, defined learning as a dynamic capability, placing emphasis on the continually changing nature of organizations. Newell and Edelman (2008) held a similar view of project-based learning as a dynamic capability since it is concerned with changing the routines. Easterby-Smith and Prieto (2008) independently argued a similar position and developed their theory by adding the mediating effect of learning capabilities. We further developed the model from Easterby-Smith and Prieto in the project context (see **Figure 8.3**). The model also echoes insights from the general trend and several vital studies on project-based learning in the literature (framed in **Figure 3.3**).

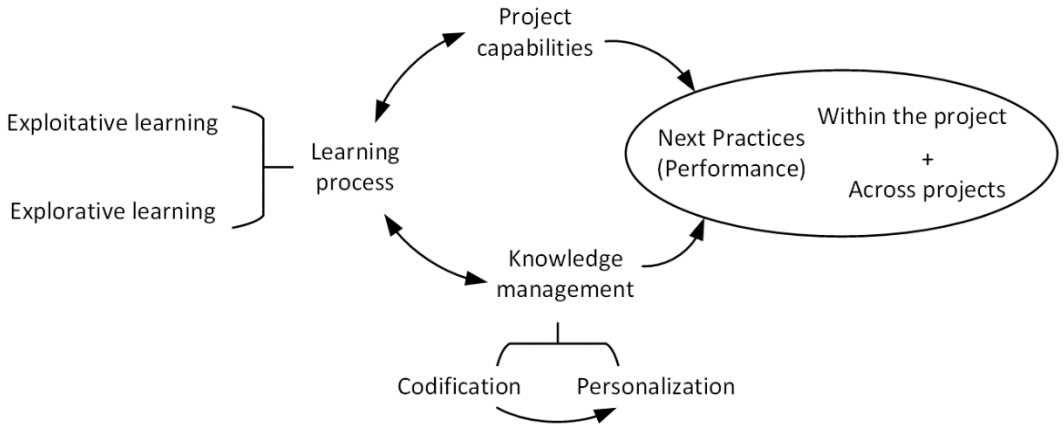

Figure 8.3 An integrative framework linking learning, capabilities, and performance (adapted from Easterby-Smith and Prieto, 2008)

Critical project-based learning processes consist of both using existing knowledge (exploitative learning; Chapter 6 Case GSP) and creating new knowledge (explorative learning; Chapter 7 Case HZMB). Even though exploitation and exploration are handled separately in Chapter 6 and Chapter 7, instances of ambidexterity were observed in both cases. The blending of exploitation and exploration is recommended to promote project-based learning. Knowledge management lies in the potential to conduct both codification (technical process; Chapter 4 project case base) and personalization (social process; e.g., Chapter 5 Case MWW). Knowledge management can be enhanced by learning from both exploitation and exploration, while technical and social elements can provide complementary resources to the learning processes.

Project-based learning is a central mechanism that links knowledge management and project capabilities together. In line with the original integral framework from Easterby-Smith and Prieto, the bidirectional arrows to and from learning processes indicate that there is mutual interaction between learning processes, project capabilities, and knowledge management. By learning capabilities, a project-based organization can build new project capabilities and transform itself into the next practices within the project and across projects to have an impact on the project performance.

Learning is changing in a dynamic environment in which issues are ambiguous. Innovation processes are triggered by interaction. It is about optimizing the learning capability, recognizing and thinking through assumptions and patterns of action. This requires reflecting on one's thinking, acting, and learning, on underlying assumptions that determine how project managers observe, interpret, define problems, analyze, conceptualize, act, and interact, as we argued in the five project-based learning principles. This form of learning is learning by communicating and exchanging with others, asking for reflection, or more easily learning from learning (McClory et al., 2017).

Based on the close relationship between learning and capability, we argue the research on project capabilities needs to pay attention to learning capabilities. Project-based learning with multiple parties can leverage existing capabilities and create new knowledge (Edmondson, 2012).

8.6 Conclusion

This research provides new insights into learning in the project setting. The project is temporary, but partners' long-term stable business relationships characterize the project's context. The research aims to gain a deeper understanding of how project participants can learn from their involvement in one-off complex projects and build capabilities to deliver them better.

A cross-case analysis of the MultiWaterWork program and Gaasperdammer tunnel project in the Netherlands, and Hong Kong–Zhuhai–Macau Bridge in China, was performed. The empirical evidence gathered in this research forms five project-based learning principles: 1)

Owner commitment, 2) Social environment approach, 3) Collaboration vision, 4) Value orientation, and 5) Open mindset. We admit that project-based reflecting and analyzing remains on the agenda when considered necessary by the owner and concerned project participants. Collaboration provides the project-based organization with access to new human and intellectual resources. Collecting lessons learned from each other and fitting the line of thought with the learning process is better done in the social environment. We encourage a service logic (of solving the client's business problem) rather than the management logic (of keeping the project on track) (Grabher, 2004). As a cognitive and experiential undertaking, learning requires us to embrace new ideas even outside our industry, allow mistakes, compliment staff for giving bad news, and experiment with trial and error.

We argued that learning is related to project capabilities, which has been proven by case studies. This is in line with the model Easterby-Smith and Prieto (2008) developed, stating that learning is considered the central mechanism that links dynamic capabilities and knowledge management. Brady and Davies (2004) have an interesting point of view on project-based learning. They believe that project-based learning can be analyzed and understood to build project capability over time. In this sense, project capability refers to the specific knowledge and experience required to engage with customers and set up and implement projects. Overall, this research contributes to rejecting the notion of project management as a best practice toolkit, which is always applicable and useful, to instead direct attention to which sets of capabilities should be deployed. We recognize that project-based learning and project capabilities lead to better business and project performance. This research underlines an essential capability for project management to develop, i.e., learning capabilities. It prepares for tomorrow in infrastructure development projects.

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Preamble

"Tell me, and I forget. Teach me, and I may remember. Involve me, and I learn."

--Benjamin Franklin

Chapter 9 Conclusions

Abstract

This chapter concludes the thesis by revisiting the research questions and summarizing the work. The PhD research addresses the topic of learning in the context of infrastructure projects. The early phase of the study consists of a review of the existing literature on knowledge management and organizational learning in project settings and an empirical overview of project case bases worldwide. This leads to the original research problems and gaps identified from the literature and practice. Three case studies were carried out, respectively, in the MultiWaterWork program, the Gaasperdammer tunnel project both in the Netherlands, and Hong Kong–Zhuhai–Macau Bridge in China. The research investigated specific learning mechanisms that emerged, including value co-creation, exploitative learning in inter-organizational projects, and explorative learning in megaprojects. A cross-case analysis reveals five project-based learning principles to achieve project capabilities, which in turn contribute to the project and business performance in the next practices. The research proactively reflects on what has been done by project managers and gives an insight into what should be done differently. It aims to contribute theoretically to learning in adaptive project management and change practitioners' attitudes and actions to adapt to the dynamic and complex future projects. The final section reports on the limitations of the research and provides directions for future research.

9.1 Conclusions of this dissertation: Learning of learning

The fragmented AEC industry has a track record of being dysfunctional. Past efforts are spent on ex-post remediation instead of ex-ante prophylactic or proactive measures. This concern about the failure of project-based sectors to identify and apply lessons is not new. However, innovations that have come about in recent years have not been adapted or formulated at the project level. So often, we continue to reinvent the wheel. Project-based learning might appear to be straightforward, but in practice, it is challenging.

This study aimed to understand better how learning occurs in large infrastructure projects and how this contributes to project management performance. The research shows that project participants attach great value to project-based learning, but more can be done in practice collaboratively through exploitation and exploration in a more social way. Our research conducted triple loop learning: learning about learning and learning for projects. The triple learning loop moves from the reflective practice of acting differently to the transformative practice of thinking differently. It is critical to reflect on past role play, values, relationships, and the context of projects.

Q1: What is the state of the art of the current learning in project studies and practice?

The research reviews the literature on learning from a project perspective in Chapter 3. Current views on the learning generated by projects are ambivalent. The review suggests that there is still no consensus on the definition of project-based learning. The terminology has not been explicitly defined in the literature. There is a significant overlap between knowledge management and project-based learning. The leading theory is adopted from organizational learning, but the link between project-based learning and organizational learning may be far from seamless (Swan et al., 2010). Early initiatives in knowledge management focused on providing electronic databases and expert systems. Traditional knowledge management activities fail to realize the constructive social nature of learning. The evolution of learning perspectives exhibited a shift from hard skills toward soft skills. Two learning perspectives, codification and personalization, are considered complementary rather than exclusive views,

giving rise to an integrative socio-technical perspective.

There is a central paradox. Compared with operation-based organizations, projects are seen as excellent models for generating new knowledge and solving problems, at least partly due to their temporary, multi-disciplinary, fluid, and goal-oriented nature. These qualities seem to make the transfer of new knowledge between projects and even within stages of projects much more challenging (Bakker et al., 2011). Learning is now seen as something extra and not as an integral part of the whole project.

However, there is not much difference between project-based learning and organizational learning in terms of the learning mechanism. Prencipe and Tell (2001) provided a clear framework distinguishing three learning processes: experience accumulation, knowledge articulation, and knowledge codification both at the project and organizational levels. Learning from successes and failures from past projects internally and similar projects externally can provide significant benefits. Still, in practice, it is not an applied strategy at the core of the routines of project managers (Hertogh et al., 2008).

There are two types of project-based learning, learning during the process, and learning after the completion. Many post-project evaluations have been done. Learning after completion can bring the best practices and lessons learned. It is still the primary and most important learning tool to capture project knowledge (Carrillo et al., 2011). Chapter 4 provides a comprehensive review of seven main project case bases in academia and practice. The current kind of project case base focuses on facts and figures, giving some general conclusions. Some emerging issues mainly related to operation types, adopted methods, data collection and analysis scope, and limited access to project data, restrict project case bases to achieve more functions. Broadly speaking, many organizations only partially invest and engage in collecting lessons learned in a database but gaining limited visible benefits (McClory et al., 2017). Learning captured is not being shared and transferred effectively, and it is ineffective to make full use of learning in the database for reuse. The project case base should not only be seen as a repository of explicit knowledge but more accurately seen as the product for fine-tuning the ability to capture and transfer knowledge from one project to another.

Earlier measures mainly focus on the technical actions to be taken, namely a prescriptive approach, which provides detailed knowledge management standards and procedures. The majority of these learning endeavors in and from projects adopt a 'sender/receiver' approach (Hartmann and Dorée, 2015). Our literature review and empirical overview rejects the position of project-based learning as a best practice toolkit for immediate use and emphasizes that there is no pure copy-paste knowledge learned from one project to another.

Currently, the overarching elements are twofold: (1) project managers accept the importance of learning from projects but tended to ignore lessons learned and execute the projects at their discretion to suit their goals; (2) a deficiency of organizational controls and routines to support and facilitate an environment of project-based learning (Love et al., 2019). Knowledge must be returned to practitioners in an accessible and constructive form so that they can integrate that into their knowledge building process. It is now accepted that effective learning cannot be achieved with information technology and document repositories alone. Social networks play a significant role in knowledge sharing and transfer.

Q2: How is learning achieved at the level of the large infrastructure projects?

The real-life example should help to have a first-hand account of the significance of good practices. In each of three case studies, a specific learning mechanism was emphasized, including value co-creation, exploitative learning in inter-organizational projects and explorative learning in megaprojects respectively. Our empirical data painted a more detailed picture of the multi-dimensional nature of project-based learning. In contrast to traditional projects, which are assumed to be pre-specified at the outset and then executed with little learning anticipated, complex large infrastructure projects cannot be fully planned and require continuous learning over their life cycles (Ahern et al., 2014). The key findings point to the importance of the social side of learning, when compared to prevailing emphasis on knowledge management (which the candidate equates to information databases) and post-project lessons learnt. It is essential but challenging in a complicated context and calling for more social interactions.

In the management of the project or program, the front-end should be emphasized in order to create a governance structure that will enable the achievement of the goals (Artto et al., 2016). Learning is a value improving practice. At the front end, the co-creation sessions helped mobilize the stakeholders to create the right values-in-use for executing the program. In the case study of the MWW ship lock program in the Netherlands in Chapter 5, the research digested three sets of values-in-use: commercial, intellectual, and collaborative values. Co-creation sessions provided stakeholders with an opportunity to discuss their competing values-for-firm and an opportunity to discuss the owner's ambition to implement abstract values of equality, trust, and openness in the program. A collaborative learning community seems to be an exciting opportunity to improve this collaboration and make learning a long-term goal.

The literature shows a lack of formal structures and incentives to enable learning to be institutionalized during the project execution phase (Scarbrough et al., 2004). In the case study of the Gaasperdammer tunnel project in the Netherlands in Chapter 6, an exploitative learning trajectory program has been set up in collaboration between the owner and the contractor to provide a space for open dialogue, and this was generally experienced positively. Profound learning happens when people share their experiences, ask questions, and tell stories. It is called social learning. The owner and contractors believe that social interaction is the most effective mode of learning. They emphasize understanding the context of the knowledge captured and transforming the resulting expertise into social practice (Gardiner et al., 2018). Better performing teams admit to errors and discuss their occurrence (Edmondson, 1999). An external knowledge party was introduced and looked at the project with an outsider's view and explained the insiders' reflections that they could not visualize themselves. Learning stimulates an open mindset, and this has a positive impact on collaboration.

Megaprojects are seen as voyages of discovery (Chudson and Hirschman, 2006), which depend on creativity and innovation while underway to achieve project goals. In traditional project management, project managers are afraid to try significant innovations, and commonly accepted innovations take time to be fully deployed. The case study of the Hong Kong-Zhuhai-Macao Bridge in China in Chapter 7 is full of ad hoc learning situations, such as when problems that have significant impacts on the project emerge, new learning should be captured.

Explorative learning is enacted through the complementary use of owner leadership, collaboration, external resources, and experiment. Such exploration requires a fundamental shift in organizational design. It involves establishing a vanguard project to investigate the new opportunities (applied technologies and managerial concepts), encourage creative problem solving, and efforts to develop new project routines and capabilities (Davies and Brady, 2016).

On the theoretical level, the research fits in with various debates on project-based learning (Bakker et al., 2011; Hartmann and Dorée, 2015). Projects need the knowledge to cope with problems occurring over the life cycle and in particular or unique situations. Partnering arrangements might serve as engagement platforms that enable the client and market partners to co-create value on infrastructure development programs (Jacobsson and Roth, 2014). Mahr et al. (2014) highlighted the importance of integrating different actors' knowledge sets and engaging in mutual explorative and exploitative learning. Exploitative learning gives meaning to what is happening in the project. Explorative learning tends to focus on increasing complexity as it might bring more excellent opportunities for learning. In the projects as organic phenomena, we ought to start exploration (giving freedom) and slowly move on to more exploitation (consolidating) (Brady and Davies, 2004). All the above highlights the strong project-based collaboration and learning between the client and their market partners. There is a reciprocal relationship between learning and collaboration. Collaboration can enhance learning, while learning can facilitate collaboration. Our findings confirmed this theoretical relationship and suggest for the future cultivating a collaborative project culture in promoting learning. In this sense, collaboration is the fifth discipline in project-based learning (Senge, 1990).

Q3: How can learning be promoted at large infrastructure projects?

The cross-case analysis provides a structured approach to learning across projects. Summarizing the above theoretical and empirical research shows that there are two structures within the AEC industry: the top-down learning approach and the bottom-up learning approach. The top-down learning approach (formal and institutional) via organizational procedures is mainly used for business-led learning. The top management often has a better strategic

overview of what is happening in the market and the need to develop specific capabilities in order to stay ahead. They can make sure that this necessary knowledge is distributed in the project by, for instance, creating a particular learning program and database. This can bring benefits because new knowledge enters the project that is not necessarily related to the central business, yet it can increase its strategic advantages. There is a positive attitude towards the creation of knowledge communities. Therefore, knowledge exchange can best be organized by bringing together "knowledge providers" and "knowledge seekers." This can ensure that different realities come together and get meaning. In this way, learning becomes a value improving practice.

The bottom-up learning approach (informal and behavioral) without thematic priority and via experience-based initiatives mostly happens in the social environment. Informal procedures emerging from day-to-day management can better contribute to the collaboration between project participants. This approach often happens through different access to knowledge sources, experiments with good and best practices when the project starts to use new technologies, or develop new capabilities. Our case studies indicate many bottom-up learning initiatives and emphasize that learning from each other and with each other is considered necessary in different situations.

Best practices might not be easily replicable, but more general principles for project-based learning can be formulated. A cross-case analysis of the MultiWaterWork program and Gaasperdammer tunnel project both in the Netherlands, and Hong Kong–Zhuhai–Macau Bridge in China, was performed. The empirical evidence gathered in this research forms five project-based learning principles (Chapter 8): 1) Owner commitment, 2) Social environment approach, 3) Collaboration vision, 4) Value orientation, and 5) Open mindset. We admit that from the top-down, project-based reflecting and analyzing remains on the agenda when this is considered necessary by the owner and concerned project participants. From the bottom up, collecting lessons learned from each other and fitting the line of thought with the learning process is better done in the social environment. Collaboration provides the project-based organization with access to new human and intellectual resources. We encourage a service logic (of solving the client’s business problem) rather than the management logic (of keeping the project on track).

As a cognitive and experiential undertaking, learning requires us to embrace new ideas even outside our industry, allow mistakes, compliment staff for giving bad news, and experiment with trial and error. The study then focuses on the contribution of learning to achieve project capabilities.

Main research question: What is the role of learning, and how can learning be promoted at large infrastructure projects?

We distinguish the role of knowledge management and (project-based) learning in our research. We consider the interplay between knowledge as a stock category and learning as a flow category, which is in line with Mirić et al. (2013). Traditional knowledge management deals with known knowns. Learning helps us recognize known unknowns and unknown knowns. The organizational learning theory focuses on the teacher-learner relationship in which the use of "hard" (formal and institutional) methods of coordination is intended to enable knowledge transfer from one member to the other, one department to the other, and one partner to the other, which we argue is not suitable for the inter-organizational project and multi-project organizational learning purposes. Lessons were often identified and captured, with much of the information transferred successfully; however, the fit-for-purpose application was still problematic. Project-based learning follows a learner-learner relationship. It uses "soft" (informal and behavioral) coordination methods to repair the broken and inconsistent learning loop.

At the project level, proactive learning and collaboration enhance and facilitate each other. Project-based learning means both exploiting knowledge and capabilities efficiently and exploring ways to innovate and respond flexibly. In this way, project-based learning means continuous day-to-day interactions and reflections. Primarily, we emphasize the role of owner, collaboration, social environment, value orientation, and mindset change. Measures and environment that is motivational, dialogical, joint, service-logical, and tolerant of uncertainty are needed to foster learning. In this environment, the owner sets the tone for project participants to retain shared knowledge and trust, search, and use new knowledge. We collaborate to learn and collaborate in projects' autonomy, which offers opportunities to create

new and innovative knowledge. Our results show that learning plays a central role in facilitating knowledge and capabilities building. Learning should prepare for futureproofing rather than troubleshooting in infrastructure projects.

Overall, we saw that project-based learning is difficult in the development of large infrastructure. A project drawing best practices and lessons learned from the past and other projects, understanding the context by communicating with stakeholders, and reusing them to develop fit for purpose project management solution, is much more likely to be delivered successfully. The project-based learning processes work beyond the project's charter with a dedicated learning strategy and accompanying structure to support implementing this strategy and a sub-organizational (project) culture that explicates learning.

9.2 Theoretical contribution

9.2.1 Rethinking project management

From a PMBoK perspective, this study unravels the contribution of learning scholarship in the areas of integration management, communication management, (human) resource management, and stakeholder management. Our understanding of project management, especially the management of large infrastructure projects, is evolving. Project management studies originated from the engineering and technology disciplines and were renowned for being practitioner-driven, atheoretical, and process-centric (Betts and Lansley, 1995; Engwall, 2003; Kwak and Anbari, 2009; Laursen and Svejvig, 2016). For a long time, the way we managed projects has mainly remained the same. Project management disciplines have emerged from the technology and engineering disciplines with different ontologies, epistemologies, and theoretical underpinnings to organizational studies (Söderlund, 2004). One of these recent phases was the “Third Wave” from the 2011 Oxford Handbook of Project Management, which focused on "project management as a core business activity, vital to organizations as a whole" (Flyvbjerg, 2013, 760). This phrase stimulated the development of theories that are more holistic (generalist) and much less specific ("from project-based theory to the more general theory" (Flyvbjerg, 2013). The dominant, rational view of project management as accomplishing a clearly defined cost and schedule goal and quality requirements does not fit

today's market and environment (Müller and Klein, 2018).

APM, PMI, and IPMA standards and project studies literature often emphasize uniqueness as a vital qualifier of projects. The discourse in cases often included terms emphasizing its uniqueness and complexity. However, a project is not entirely unique; it is embedded in its history and context (Engwall, 2003). Among all case studies in this research, the projects were not purely temporal but carried elements of constancy (Brookes et al., 2017; Papadonikolaki et al., 2019). They have a lot in common, but they also have much to learn from each other, to improve performance. Large infrastructure projects are no longer a closed system that can be separated from the environment. In terms of the management of complexity, the uniqueness of projects means that each project requires tailor-made solutions. This does not make learning fruitless; however, it can help the management of projects since patterns of evolution and similarities can also be found (Hertogh and Westerveld, 2010).

It has been suggested that project managers should have longer-term perspectives rather than focus only on time, scope, schedule, or quality. Routine project management has demonstrated great power in predicting and controlling. Project managers have an annoying predisposition to look at things in the short term. Project success has moved from meeting the criteria of creating value to co-creating value with stakeholders. The future requires a need for adaptive project management. The evolution of project management can be supported by **Table 9.1**, a vital contribution from the Project Management Congress 2019 in Delft, the Netherlands. Learning should be included as a project success criterion to make a full assessment of the successful project that manages to deliver within the expected performance and contribute to learning (Arthur et al., 2001). Project-based learning or innovation through projects is an exciting topic to address, especially in the context of multi-stakeholder environments such as megaprojects. New project management types are required for inter-organizational projects, programs, and megaprojects (Crawford and Pollack, 2004; Gustavsson and Hallin, 2014; Pollack, 2007).

Table 9.1 Necessary shift in emphasis from AT Osborne

From	To

Scope definition at the start of the project	Continuous dialogue about scope definition
Project manager as a guard	Project manager as a diplomat
Future user and maintainer involvement during project (scope) definition	Continuous involvement of future user and asset manager
Controlling cost, schedule, and quality	Controlling the decision-making process
Detailed planning	Learning approach
Organizing by the division of tasks and responsibilities	Organizing by emphasizing shared responsibilities and shared mental models

9.2.2 Knowledge management

The meaning, status, and influence of each theoretical element in different cases are concerned with knowledge management. The boundaries of the project knowledge and the conditions of their application are defined and clarified. We confirmed the broad overlaps between knowledge management and the learning concept. It is in line with Prencipe and Tell (2001) that learning processes are organized around experience accumulation, knowledge articulation, and knowledge codification.

However, the more critical is the distinction. A "learning" perspective rather than a "knowledge management" perspective is adopted for this research. Here “learning” is viewed as a process whereby project participants' views and interlocking behaviors are sourced within an “organization” perspective. Knowledge management is not enough to fully understand real dynamic communication in projects and provide an efficient solution to complex management learning. Our research advocates a shift from the trade-off attitude to the potential to implement codification and personalization, exploration and exploitation activities simultaneously. As more and more knowledge management research turns to develop technical IT tools and systems to build the knowledge management infrastructure, adopting a learning concept will focus on the social process for tacit knowledge sharing and reusing. Project-based organizations should create a social context to enable the reuse of knowledge (Bartsch et al., 2013).

9.2.3 Organizational learning theory

Research on organizational learning in project management has increased significantly during

the last few years. A large amount of literature aiming at expanding the understanding of organizational learning has been produced (Chiva et al., 2007). In recent years, research on the concept of learning has dramatically evolved, and the extent reaches beyond individuals and organizations to encompass projects. However, a theory developed at the organization level of analysis is hard to apply equally to the project level of analysis without adaptation (Makadok et al., 2018). Learning in itself is not new, but considering it as an integral part of project-based learning is not always done.

This research contributes to a deeper understanding of improving projects by combining perspectives from organizational learning. Reviewing extant literature on project-based learning, the research finds that the two domains, project and learning, have evolved in parallel and progressed disconnected from each other. Currently, there is hardly any systematic agreement in project-based learning. The research is arguing that project-based learning is different from organizational learning. Simply copying and pasting knowledge would possibly fail due to a lack of contextualization. Learning within the project does not automatically lead to organizational learning, and organizational learning theory cannot be directly used in the project setting. We make three main contributions in this research to facilitate communication between organizational learning theory and project studies.

1) Project-based learning may need to be more inclusive of the peripheral logic (in our case with a "project logic"), which is dominated and often dismissed by the more assertive logic (with an "enterprise logic"). These two levels present competing logics. This may result in actors on the peripheral logic's side not being heard or included, inhibiting an inclusive organization development. Where enterprise logic focuses on sustainability and is willing to sacrifice growth for stability and continuity, project logic is less risk averse. Actors on the project logic side have a strong appetite for growth and change, are willing to engage in uncertain, entrepreneurial activities, even at the expense of stability, and are therefore averse to underutilization of resources and missed opportunities. The research found that one logic (enterprise logic on the side of headquarters) dominates. In contrast, the other (project logic on the side of the subsidiaries) struggles to survive or have an impact.

2) For a unique project, it does not mean that it is utterly dissimilar to all other projects. Instead, projects do resemble each other (Crawford and Pollack, 2007). Since projects characteristically involve developing and producing new products and services, there are plenty of opportunities for novel ideas to emerge, and for exploitative and explorative learning to occur (Ramaprasad and Prakash, 2003).

3) Temporary organizations have been conceptualized as inherently different from relatively permanent organizations. Despite advances in the collation and dissemination of knowledge from projects, this does not translate into improved performance within projects. They continue to experience very similar mistakes being committed inside major projects. They are skeptical that the learning outcomes are static knowledge. Learning is not a stable process, but an ongoing and dynamic social co-creation engaged by project participants in practice (Orlikowski, 2002). Knowledge sharing and transfer are primarily made through social contacts and peer-to-peer connections rather than through formal processes (Dutton et al., 2014). Noteworthy to mention is that this sharing of knowledge is done in an ad-hoc way and is neither documented nor structured.

This PhD research moves from capture and storage mechanisms to developing a knowledge-friendly culture that encourages learning and reflection among project participants. The research elaborates on projects' role, especially the large infrastructure projects, to drive and foster learning. Learning involves looking retrospectively at past projects and looking prospectively to new practices. Projects may benefit not only the performance of future projects but also the training and development of sufficient managerial and technical personnel in the long term when learning is systematically incorporated into their project management processes (DeFillippi, 2001).

It is vital to require the emergence of new meaning and understanding to initiating learning. The research pushes the boundaries of our understanding of organizational learning theories. It contributes to the interpretation of organizational learning and its different definitions. It is a complement to organizational learning, not a replacement.

9.3 Practical implication

9.3.1 From database learning to social learning

Conventional knowledge management techniques such as post-project review, training, and standard procedures documentation remain important (Pitsis et al., 2014; Schindler and Eppler, 2003). There are no guidelines on structured ways of analyzing projects and retaining lessons learned for future projects and few for building practical organizational capabilities and competencies. It is often not easy to find a solution; if it were, we would have found it a long time ago. Often, several different issues are at play.

Formal information management systems exist both within the project and across the projects. Many infrastructure organizations and projects tried to use a database system to store knowledge from previous projects, but it failed due to numerous reasons. Establishing a knowledge management system will not automatically generate a learning environment or lead to greater understanding. The overview of the current project case bases reveals that the value of learning is not the information itself but the dialogue about information. Experiences in the cases show that learning between projects is best accomplished when people meet. Project participants can quickly determine where they need to pay extra attention to in their project and from whom they can obtain more information about this. We are convinced that the knowledge is with the people and not in a database. There is a shift from the rather simplistic traditional sender-receiver model to a socially complex learning process (Hartmann and Dorée, 2015). Most learning happens through social contacts and peer-to-peer connections (Dutton et al., 2014). Social channels are more useful for distributing highly context-specific knowledge (Wiewiora et al., 2010). Internal teams and their networks are the commonly used current way, while networks with outside parties have been found to be significant for greater knowledge exchange. It is thus analytically vital to make a distinction between knowledge management and project-based learning.

The insights gained show that the management of large infrastructure projects has a technical component, but the essence lies on the social level. We see that parties do have contact but do not learn from each other and do not really cooperate. Do not work in an isolated world! It calls

for mobilizing and engaging everyone into an “extended community of practices,” fostering collective social learning instead of technocratic optimization.

The vast majority of the knowledge is stored in the minds of the project team members in a non-coded form, so the knowledge transfer subject is usually an individual team member. Project-based learning should use the most active dynamic knowledge carrier, the person's rich practical experience, and tacit knowledge stored in the brain. Within projects, people can co-locate and build relationships. Between projects, relationships are less intensive and mostly concentrated in the community of practice that speaks the same language and thinks in a similar way. Senior people and major contractors move on to other projects. They become the clients' preferred delivery partners. A typical example is that Mr. Andrew Wolstenholme, the program director of Heathrow Terminal 5 (T5), became chief executive of Crossrail. Learning began to be carried forward.

9.3.2 Mindset and cultural change

The current global urbanization is an excellent opportunity for us to think again. Project managers need knowledge, but they also need to develop a mindset that is broad enough and deep enough. Delivering a project is more than just completing a task. It is equally an opportunity to learn. A downside of traditional thinking is that the capacities are seen as given. Knowledge is there; knowledge is static; knowledge should be captured and stored and then shared and transferred. This research calls out for learning to evolve from focusing on the toolset and skillset to mindset and culture. Mindset and cultural change are considered by the research's empirical data as a challenging task and have not been tackled seriously. Our research yields some four useful insights to practitioners.

1) The owner has a central and influential position. The owner bought the physical asset from the project and the lessons learned and best practices produced during the project process. An explicit learning assignment from and facilitated by the owner can help all project participants invest in earlier learning activities. The GSP case provides an excellent example.

2) Projects are mostly endeavors where we need different expertise to come together. Learning helps people develop trust, build relations, and establish a culture. Project participants tend to play their cards close to their chest. There should be a transition from treating projects as necessary instrumental processes to projects as social processes (Bakker and De Kleijn, 2014; Winter et al., 2006). Enabling learning in a project-based organization requires far more attention to attitudes towards learning than a focus on establishing procedures, systems, or building knowledge repositories.

3) Building a community of practices can promote the sustainability of learning through projects and the organization of reflective practice cross the boundaries of the specific and silo projects (DeFillippi, 2001). It is time to be a reflective practitioner more than a trained technician (Bakker and De Kleijn, 2014). Learning is a continuous action. There is always be room for improvement. We need to align the incentives of achieving long-term value rather than optimizing narrow particularistic short-term interests. Ultimately, it should lead to a holistic approach to learning. Currently, learning is reactive: you have to get a problem or make a mistake and then consider learning. Let us make learning proactive. It requires dedication and long term efforts. It results in capabilities of an organization that cannot be copied easily and provides a competitive advantage.

4) There are conflicts between the temporary nature of projects and the permanent nature of parent organizations. If the project can receive a specific learning assignment from the parent organization, project participants will probably not focus exclusively on their own objectives. If project-based learning is seen as only a short-term opportunity, its benefits would be quite limited. As knowledge resides with a few specialists and project managers, it calls for considerate human resources management with a long-term organizational vision.

9.3.3 Using knowledge is power

At present, everyone is in the VUCA era (volatility, uncertainty, complexity, ambiguity) (Bennett and Lemoine, 2014), and they are continually upgrading themselves to be able to

respond flexibly to all changes. Continuously learning new knowledge is also a manifestation of responsibility for the work.

The very word "knowledge" encompasses many forms of "knowing" that are more tacit and not only uncodified but often not easily codified at all. Often project managers misunderstand knowing as knowledge. They performed the post-project review as required and thought they learned and obtained the (codified) knowledge. A simple way of thinking about this idea is to collapse the distinction between knowledge and knowing (Brown and Duguid, 1998). Too often, lessons are captured but not indeed learned nor implemented. Communication efforts are spent on ex-post remediation instead of ex-ante prophylactic or proactive efforts.

Francis Bacon's "knowledge is power" is not enough. Sharing knowledge is power (Dalkir, 2013). Using knowledge is power. People make knowledge alive. Learning is a purposive process. Knowing needs to evolve into knowledge with the comparison and fusion with insights from others, contextual information to see if it is compatible and continuously upgrading. A lesson can only be said to have been learned when it has been converted, through practice and alongside other inputs into a change or refinement to how the project deals with the problems in front of it. Just in line with Kokkonen and Alin (2015, 515), "knowledge is not acquired and then used but rather recreated and reflected on by the learner." The relevance of applying lessons learned is obvious from practice as well as literature. During the cycle of the Plan Do Check Act (PDCA), Act is sometimes forgotten. Please build them into the management of projects! In fact, project-based learning especially struggles with the last mile problem and should use multiple information resources to get from origin to destination. Its usage can only determine the overall quality of learning. We call for better measures to enable participants to interact and learn more about each other (Bakker and De Kleijn, 2014).

9.4 Limitations and future work

9.4.1 Limitations

First, this study's limitation and possible sources of error can be in its explorative character and the cases' selection. The research recognizes building theory's difficulties from a small number

of case studies (Flyvbjerg, 2006). As only three cases conducted in the Dutch and Chinese context were considered in this research, the conclusions should be regarded with some reservation and cannot be over-generalized. We do not argue that the approaches from the three cases represent the only strategies. It does not aim to select the best among potential solutions but instead devotes energies to federate on a recommended one. It is suggested that the findings should align with the experiences of infrastructure projects in other parts of the world with different cultural backgrounds. Future research would benefit from how this research can be expanded further by more theoretical sampling approaches and the inclusion of other projects, programs, or mega projects to confirm or disconfirm our findings. Surveys are probably required among a greater variety of organizations (e.g., the owner, general contractor, sub-contractor, and consultancy firm; transport and energy).

Besides, we did not collect the empirical performance data. We do not extend the analysis to consider direct and causal relationships between project-based learning and project performance (i.e., financial and non-financial quality, reputation, growth). The link's empirical testing can be established to prove how project-based learning precisely affects project business performance.

9.4.2 Future work

Project management scholars have moved towards approaching projects from more systemic perspectives, looking beyond a single project (Geraldi and Söderlund, 2018), that projects are their own complex systems and part of larger organizational and societal systems. The recent intensification of and difficulties associated with project-based learning asks us to reconsider the relationship between temporary and permanent organizations (Riis et al., 2019; Sydow and Braun, 2018; van Marrewijk et al., 2016). We observed the projects in terms of local adaptation, noticing the distance between the project and the parent organizations. Learning at the level of projects linking a project to its broader social context remains understudied. This is also in line with bridging the gap between project-based learning and organizational learning so that project studies can be extended to further impact and contribute to more general management and organization studies (Jacobsson and Söderholm, 2020).

This research has concluded that lessons were often identified and captured; however, the fit-for-purpose application was still problematic. This hierarchical system has been proved less effective, so we call for more social factors in this research. Now thanks to the rapid development of digital innovations such as big data, cloud computing, and artificial intelligence (Lobo and Whyte, 2017), a large amount of past research and practices on IT focuses on centralized knowledge repositories and codified knowledge. Many infrastructure development organizations are now looking at the recent development of digital innovations, which this research did not consider. The ideal representative project case base study relies on the database's size and wide geographical coverage (Van Wee, 2007). Current project case bases are far from comprehensive and need to be expanded, and more intelligent data analytics are required. The project case base would be the basis for producing evidence that draws upon qualitative and quantitative methods to provide a range of best practices and lessons learned for tackling each of the challenges. Using different data to analyze the project from different angles can help determine the characteristics that we did not know in the past. Currently, technologies to rapidly articulate and codify knowledge have seen a revolutionary change. It calls for a structured way of disseminating knowledge proactively. The increasing use of intelligent systems (such as artificial intelligence, big data, and case-based reasoning) might bring more insights into project-based learning. At present, quantitative research from the project case base can provide a valuable opportunity to verify theoretical assumptions from qualitative research. Any artificial intelligence algorithm is based on learning from the past. Data scientists aim to get an overview of the data and find fascinating new facts. However, they have little to no knowledge of the data, and the requirements are often vague and abstract. How can users write database queries? Can we investigate the social aspects of projects more thoroughly? Can we capture the social context in a kind of database? It is clear that infrastructure projects are becoming more complex and project managers for sure have more to learn. We expect the new technology-driven project-based learning to be more people-centric and provide more proactive recommendations for the next practices.

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Since 2019, I have been in the lecture team of some Construction Management and Engineering Master and Project Management from Nano to Mega Minor program courses (Fit-for-purpose Project Management, Collaborative Design and Engineering, Dynamic Control of Projects, Methodology for Scientific Research, Integration: technical project). I never expect to give lectures and workshops in a social distancing situation. Working at home often had to work twice as hard as we suddenly had to start teaching online. I have a great deal invested in preparing, lecturing, interacting and grading. Students' positive evaluation and personal thank you emails afterward blurred my eyes. "Yan Liu was one of the most approachable lecturers I had at TUD. He was available to us almost 24/7, literally." "Again, we love you, Yan!" "Yan is a great lecturer as well!" We even got an alias Erik-Yan. All my efforts paid off!

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Joining the academic publication review process earlier in the PhD stage is a key course for me to learn how to write articles for leading journals and respond to critical comments. I highly appreciate dozens of opportunities to review manuscripts given by editors from best journals in the field, including International Journal of Project Management, Automation in Construction, Journal of Management in Engineering, Project Management Journal, Transactions on Engineering Management, Construction Management and Economics, etc.

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Yan Liu

Delft, The Netherlands

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Curriculum Vitae

Yan Liu obtained his bachelor and master degree Construction Management from Chongqing University, China (supervised by Professor Shirong Li, the CIOB's first female president). Before starting his PhD, he acted as a researcher at RCICEM (Research Center for International Construction Economics & Management) of Chongqing University, a visiting PhD at Delft University of Technology (6 months) and Australasian Joint Research Centre for Building Information Modelling Curtin University on Building Information Modelling applied research.

During his PhD, Yan published 4 journal papers as the first author in International Journal of Project Management (with one ESI Highly Cited Paper), Engineering, Construction and Architectural Management etc., 3 journal papers as the corresponding author and 4 journals papers as the co-author. He joined the translation from English to Chinese of several books, including Code of Practice for Project Management for Construction and Development fourth edition by CIOB (Chartered Institute of Building), the Oxford Handbook of Megaproject Management edited by Bent Flyvbjerg, Managing Large Infrastructure Projects: Research on Best Practices and Lessons Learnt in Large Infrastructure Projects in Europe, 10 Years of Managing Large Infrastructure Projects in Europe both by NETLIPSE (Network for the dissemination of knowledge on the management and organisation of large infrastructure projects in Europe), Playing with Complexity Management and organisation of large infrastructure projects by Marcel Hertogh and Eddy Westerveld.

Yan is a regular reviewer of International Journal of Project Management, Automation in Construction, Journal of Management in Engineering, Project Management Journal, Transactions on Engineering Management, Construction Management and Economics, Urban Planning.

Yan was appointed as Researcher from November 2019 until February 2022 and participated in the education of Construction Management and Engineering Master and Project management from Nano to Mega Minor courses (Fit-for-purpose Project Management, Collaborative Design and Engineering, Dynamic Control of Projects, Methodology for Scientific Research, Integration: technical project etc.) and MOOC online activities. He supervised 13 master theses (11 from Delft University of Technology, 1 from Vrije Universiteit Amsterdam and 1 from University College London), 11 master research internships, 2 bachelor theses and 2 civil engineering consultancy projects. He is supervising around 10 master theses currently.

Yan was a visiting PhD at the Bartlett School of Construction and Project Management, University College

London funded by Sylff Research Abroad (part of the Ryoichi Sasakawa Young Leaders Fellowship Fund (Sylff) Program). He also participated the collaboration with Nanjing University, Tongji University, Chongqing University, The University of Hong Kong, UCL and Hong Kong–Zhuhai–Macau Bridge Authority. He is a member of China Highway & Transportation Society the European Committee.

Yan acted as the chairman of PromooD (the representative body for all PhD students at TU Delft), vice president of the Association of Chinese Students and Scholars in the Netherlands-Delft Branch, board member of TU Delft Doctoral Education Programme Advisory Board. He co-founded the PhD council of Faculty of Civil Engineering and Geosciences and became the first representative of the Department of Materials, Mechanics, Management & Design (3MD).

List of Publications

Journal Articles

First author

Liu, Y., Van Nederveen, S., & Hertogh, M. (2017). Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International Journal of Project Management*, *35*(4), 686-698. (ESI Highly Cited Paper)

Liu, Y., van Nederveen, S., Wu, C., & Hertogh, M. (2018). Sustainable infrastructure design framework through integration of rating systems and building information modeling. *Advances in Civil Engineering*, *2018*.

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Liu, Y., Amini-Abyaneh, A., Houwing, E., Hertogh, M., Bakker, H. Collaborate to learn and learn to collaborate: a case of exploitative learning in the inter-organizational project. *Engineering, Construction and Architectural Management* (accepted)

Corresponding author (*****)

Zeng, N., **Liu, Y.***, Mao, C., & König, M. (2018). Investigating the relationship between construction supply chain integration and sustainable use of material: Evidence from China. *Sustainability*, *10*(10), 3581.

Liu, H., Jiang, C., **Liu, Y.***, Hertogh, M., & Lyu, X. (2018). Optimism bias evaluation and decision-making risk forecast on bridge project cost based on reference class forecasting: Evidence from China. *Sustainability*, *10*(11), 3981.

Zeng, N., **Liu, Y. ***, Gong, P., Hertogh, M., König, M. Do right PLS and do PLS right: A Critical Review of the Application of PLS-SEM in Construction Management Research. *Frontiers of Engineering Management* (accepted)

Under review

Liu, Y., Houwing, E., Hertogh, M., Yuan, Z., Liu, H. Explorative Learning in the Infrastructure Development Megaproject: a Case from the Hong Kong-Zhuhai-Macao Bridge. *Project Management Journal*

Zhang, X., Le, Y., **Liu, Y.***, Chen, X. Unpacking Ambidextrous Innovation in Infrastructure Projects: Measures and Mechanisms. IEEE Transactions on Engineering Management

Other publications

Wang, X., Ren, H., Cai, W., **Liu, Y.**, & Luo, L. (2016). IdentIfIcatIon of drIvIng factors for green BuIldIng development In chIna. *Open House International*, *41*(3), 92-96.

Xiahou, X., Yuan, J., **Liu, Y.**, Tang, Y., & Li, Q. (2018). Exploring the driving factors of construction industrialization development in China. *International journal of environmental research and public health*, *15*(3), 442.

Tong, R., Zhai, C., Jia, Q., Wu, C., **Liu, Y.**, & Xue, S. (2018). An interactive model among potential human risk factors: 331 cases of coal mine roof accidents in China. *International journal of environmental research and public health*, *15*(6), 1144.

Le, Y., Zhang, X., **Liu, Y**., Liu, M. Exploring the Links between Cross-functional Team Diversity and Ambidextrous Innovation in Infrastructure Projects. *Journal of Construction Engineering and Management* (accepted)

Mentoring Experience (selected)

2017 Inter project learning: Key steps and actions to effectively reuse lessons-learned by managers in new projects. Daily supervisor

2017 Best practices for effective implementation of project strategy. Daily supervisor

2018 The impact of "learning" in the construction of the Gaasperdammertunnel. Daily supervisor

2019 Process standardization in the construction industry: An explorative study into the right balance between standardization and flexibility. Daily supervisor

2019 Elevating decision-making for maintaining inner-city quay walls. Daily supervisor

2019 Knowledge sharing in agile projects: Exploring knowledge sharing patterns in agile projects around Philips Research context. Daily supervisor

2019 Cost-conscious designing of Dutch transportation infrastructure projects: A first explorative research into the 'control' based factors for reducing the front-end cost escalations. Daily supervisor

2020 Scope creep in onshore wind farm projects: A study on scope creep in onshore wind farm projects governed by FIDIC yellow book. Daily supervisor

2020 Influence of collaboration on the management of BIM-based construction projects: An analysis of the perspectives of project team members. Daily supervisor

2020 Supporting leadership development through psychologically safe experiential learning: A grounded theory on engineering education. Daily supervisor

2020 Understanding the schedule delay within design-construction interface. Daily supervisor

2020 Information as a product: Bridging the gap between BIM technical and social solutions in projects for O&M purposes. Daily supervisor