Bridging Minds for Building the Future

Facilitating Inter-Organizational Collaboration for Next-Generation Infrastructures

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Maryam Rikhtegar Nezami

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Dissertation

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Keywords: Inter-organizational collaboration; Interconnected infrastructure projects; Inter-organizational project management.

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List of Abbreviations

DA	Data Analysis
DG	Data Gathering
EC	Enhancement Cycle
FB	Feedback
ICAT	Inter-Organizational Collaboration Assessment Tool
ICC	Individual Collaborative Capacity
IOC	Inter-Organizational Collaboration
IOCF	Inter-Organizational Collaboration Facilitation
IOP	Inter-Organizational Project
NGI	Next-Generation Infrastructure
OCC	Organizational Collaborative Capacity
RCC	Relational Collaborative Capacity

Summary

Next-generation infrastructures are needed to cope with multifaceted demands of our rapidly evolving world. Technological progress, societal needs, and sustainability goals all need to be accommodated. Future infrastructures must integrate a variety of advanced technologies such as artificial intelligence, the Internet of Things (IoT), renewable energy systems, and smart materials to create more efficient and interconnected networks. The networks need to be designed so that they can accommodate to meet the rising connectivity demands while also supporting environmental sustainability. However, their development is loaded with challenges.

Infrastructure operators play a crucial role in balancing the diverse and often competing demands and requirements for infrastructures and their services. The complexity of the task highlights the importance of strategic decision-making in infrastructure design, as these decisions can significantly shape societal outcomes. With the increase in urbanization, next-generation infrastructures are expected to optimize transportation, facilitate the creation of smart cities, and enhance the overall quality of life. Additionally, they must ensure resilience against disasters and cybersecurity threats. Furthermore, investments in these infrastructures can boost global competitiveness, attract innovation, and drive economic growth. Nevertheless, addressing the needs of a technologically advanced and interconnected world requires a careful consideration of societal impacts and a balanced approach to sustainability, efficiency, and resilience.

Infrastructure encompasses essential systems including physical constructs like roads, bridges, and utilities, as well as intricate socio-technical networks such as telecommunications grids. Infrastructure sectors were traditionally managed in relative isolation. However, the evolving landscape of societal needs, environmental dynamics, and technological advancements demand increased

recognition of the interconnected nature of current day infrastructures, as assets increasingly influence each other. Recognizing these interdependencies is crucial for effective design and management of future infrastructures under a variety of conditions which include crises and infrastructure failures. Failures in one infrastructure can cascade to others. Asset managers who operate independently with their own specific way of working, must increasingly work closely together to design and operate these interconnected systems. This collaborative approach is essential for designing and managing the next generation of infrastructures to ensure their stabile and resilient performance.

The design and management of next-generation interconnected infrastructures involves numerous complex challenges. These include specific technical issues, such as system reliability and scalability, but also dealing with security threats, regulatory compliance, and societal impacts. For example, ensuring reliability and resilience requires meticulous planning to ensure resilience despite system failures and dealing with unexpected increased demand. Moreover, integrating energy-efficient solutions is critical for reducing environmental impact and operational costs, and this needs to be clearly linked with other design aspects. Overcoming the challenges is fundamental for developing robust, secure, and efficient infrastructures. This requires ongoing collaboration, comprehensive risk assessments, and adaptive design strategies.

Six major Dutch infrastructure practitioners who collaborate within NGInfra (Alliander, Port of Rotterdam, ProRail, Rijkswaterstaat, Schiphol, and Vitens) recognize the challenges of designing next-generation infrastructures and emphasize the need for a responsive, collaborative approach. By collaborating, they aim to create robust, secure, and efficient interconnected systems which are able to meet evolving societal needs. This effort requires significant investments from a diverse range of resources, innovative capacity, and expertise from multiple disciplines. Scarcity of resources and knowledge within individual organizations emphasize the need for collaboration to address the complex

problems of next-generation infrastructures. This horizontal form of collaboration provides new opportunities to achieve innovative, resilient solutions in new infrastructure projects. Existing literature in the field of infrastructure development indicates fragmentation among the infrastructure organizations and poor quality of collaboration between them. Establishing a collaborative environment and facilitating collaboration between infrastructure owners, in other words, inter-organizational collaboration (IOC), is beneficial to achieve synergies and desired outcomes for design and development of next-generation infrastructures.

To stimulate collaboration, the main research question of the current dissertation is **how can collaboration between infrastructure owners in interconnected infrastructure projects be facilitated?**

The research focuses on infrastructure projects in which various Dutch infrastructure owners in the Netherlands collaborate. In the first step, preliminary research was performed to gain an understanding of the current state of collaboration and data sharing among the involved parties, particularly the data required at the early stages of a project to design and develop interconnected infrastructures. Semi-structured interviews were conducted at organizational and project levels with practitioners from various Dutch infrastructure organizations. The outcomes reveal that the availability and accessibility of data in interconnected infrastructure projects in which interorganizational collaboration takes place face difficulties, and that data sharing runs into fundamental problems in such projects. These challenges primarily result from a series of interconnected issues such as, data scarcity and accessibility, outdated data storage platforms, distinct data formats and standards across organizations (and infrastructure sectors), and different data management policies. However, sharing and using data across organizational boundaries is indispensable to achieve project goals in inter-organizational infrastructure projects because it facilitates collaborative decision-making and problem-solving. Moreover, data sharing stimulates

transparency and accountability among the participating organizations, which can lead to improved trust and collaboration. It also enables the application of collective intelligence and expertise, which can result in innovative solutions which can contribute to desired project outcomes. Focusing on the status of data sharing and collaboration in inter-organizational projects in the Netherlands, data sharing and collaboration were observed as tightly intertwined activities. In other words, data sharing is essential to successfully collaborate with other infrastructure operators. Conversely, a collaborative environment stimulates effective data sharing in inter-organizational infrastructure projects. This dissertation contributes to the design and development of collaborative environments among infrastructure owners, which in turn are expected to enhance data sharing in interconnected infrastructure projects.

Preliminary research revealed various challenges which hinder collaboration between practitioners during infrastructure projects. The key challenges of IOC were identified in three different inter-organizational infrastructure projects in the Netherlands.

Factors contributing to IOC were identified through literature study, interviews and were subsequently analyzed utilizing the Q-methodology to map the various perspectives of practitioners. Q-methodology offers an approach to investigate the subjective viewpoints on the researched topic, through a structured Q-sorting process, facilitating understanding of diverse perspectives. The results of the study indicate the existence of two perspectives among practitioners: a holistic goal-oriented perspective and a people-oriented perspective. The holistic, goal-oriented perspective highlights the necessity of setting common goals in collaborative projects and emphasizes the significance of both formal and informal communication among collaborators. The people-oriented perspective prioritizes the individual dimension of IOC such as respect and trust among collaborators to establish IOC in interconnected infrastructure projects.

The main factors of IOC in both perspectives include commitment, respect among people, having a common goal and a shared vision, and top management support.

To manage and facilitate inter-organizational collaboration (IOC) in interconnected infrastructure projects, it is necessary to understand the current state of collaboration and identify any issues, strengths, and weaknesses. The criteria to assess IOC were identified via two data collection methods: through literature study and in-depth interviews with representatives of infrastructure organizations with experience in cross-sectoral infrastructure projects. The resulting inter-organizational collaboration assessment tool (ICAT) (Table I). ICAT encompasses twelve criteria and thirty-six sub-criteria from three different categories of individual collaborative capacity (ICC), relational collaborative capacity (RCC), and organizational collaborative capacity (OCC). ICAT can be used to assess and design the inter-organizational collaboration (*ex-ante*) and assess its progress during and after the realization of an infrastructure construction project (*ex-post*). The ICAT enables practitioners to monitor the status of IOC and progress of collaboration in inter-organizational collaborative projects and helps them in making informed decisions to facilitate collaboration.

Table I. Inter-organizational collaboration assessment tool (ICAT)

(ICC). Individual Collaborative Capacity	i.1	Attitudes and motivations
	i.2	Attitudes about other participants
	i.3	Ability to work with others
(RCC). Relational Collaborative Capacity	r.1	Working climate
	r.2	Shared vision
	r.3	Knowledge sharing
	r.4	Relationship continuity
	r.5	Value diversity
(OCC). Organizational Collaborative Capacity	o.1	Leadership
	o.2	Communication
	o.3	Formalized procedures
	o.4	Improved orientation

A study based on action research methodology was conducted in one of the interconnected infrastructure projects in the Netherlands. The case is a horizontal collaboration between two infrastructure owners to develop a public transport hub in The Netherlands. The objective of the study was to apply the knowledge gained from the research so far and to obtain an in-depth understanding of which procedures and processes help implement IOC. Performing action research offers an opportunity for the researcher to work alongside infrastructure practitioners and integrate scientific perspectives with practical viewpoints to identify solutions that facilitate collaboration. A multi-stage IOC facilitation process (IOCF) (Figure I) was developed in which each stage includes four general steps: data gathering (DG), data analysis (DA), feedback (FB), and an enhancement cycle. Data gathering is performed through observation, interviews and assessment using the ICAT, and the collected data are analyzed to assess the collaboration status and identify potential issues. The results of data analysis are discussed during the feedback session with the infrastructure practitioners.

Subsequently, the collaboration issues are prioritized, and the possible solutions are brainstormed to implement and facilitate IOC. The output of the feedback session (FB) is fed to the iterative enhancement cycles. The focus of iterative enhancement cycles is on the prioritized issues. Depending on the type of issues and the planned actions, a few cycles can be simultaneously conducted to address different issues. The proposed process enables infrastructure practitioners to address challenges for collaboration and evaluate the overall collaboration status at the beginning of each stage using the ICAT and develop actions to improve the collaboration process in interconnected infrastructure projects. Specifically in this research project, the application of the proposed process resulted in improvements in the areas of "shared vision" and "communication".

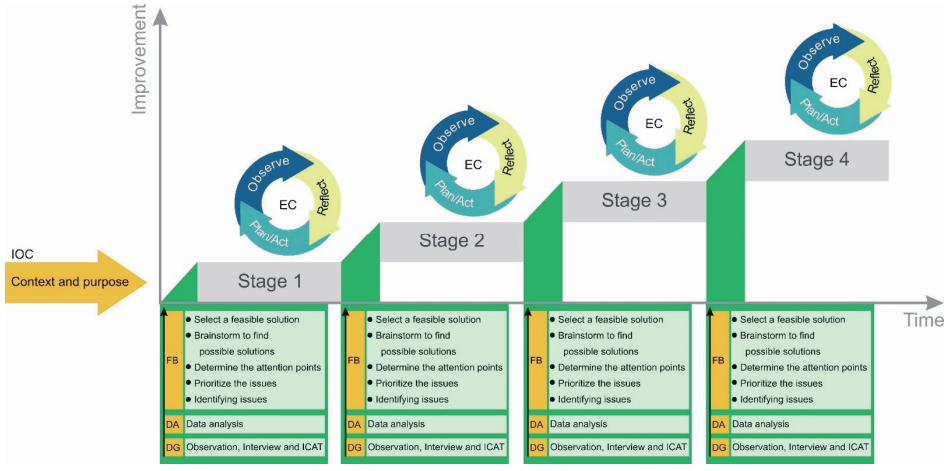


Figure I. The IOC facilitation process (IOCF) developed in the present work. Depending on the complexity of a project, multiple enhancement cycles (EC) can be defined in a stage. Moreover, the enhancement cycles can be repeated multiple times during a stage.

This dissertation sheds light on horizontal forms of collaboration and provides a comprehensive overview of the factors contributing IOC in interconnected infrastructure projects. This study uncovered the existence of a bilateral relationship between IOC and data sharing in interconnected infrastructure projects. Focusing on IOC, assessment criteria of IOC were identified, which supplements scientific knowledge on IOC and provides a tool for infrastructure

practitioners to assess the quality of the collaboration. The tool developed in this dissertation covers three critical aspects of collaboration, as summarized in Table I. Applying this tool in practice, several points of improvements were revealed supporting practitioners to improve their collaboration (see Chapter 6). Based on the results obtained in this dissertation an IOC facilitation process (IOCF) is developed that can be applied in infrastructure projects for continuous and incremental improvement of IOC. The proposed process aims to address complex and challenging issues that may arise during collaboration which aims to support infrastructure practitioners in promoting the development of innovative solutions.

Based on this study research, several recommendations are proposed for future research in IOC. Future studies could explore the preconditions necessary for successful IOC at the organizational level, particularly focusing on optimizing internal processes such as data management, communication channels, and organizational adaptability. Developing an organizational readiness assessment can help determine the readiness of an infrastructure organization for collaboration. Additionally, adopting a relational model approach to examine the relationship between factors influencing IOC, especially in interconnected infrastructure projects, could provide deeper insights into their complex interactions. Expanding the scope of research to include infrastructure organizations from diverse cultural backgrounds can reveal how cultural variations impact IOC and highlight commonalities and differences across various settings. Finally, the multi-stage facilitation process developed in this study offers a foundation for future research to identify best practices for enhancing collaboration in different contexts.

Samenvatting

De volgende generatie infrastructuren zijn essentieel om aan de veelvormige uitdagingen en vereisten die onze snel veranderende wereld stelt te voldoen. Onze maatschappelijke behoeften, technologische vooruitgang en duurzaamheidsdoelen; eigenlijk willen we ze allemaal tegelijkertijd te realiseren. Toekomstige infrastructuren zullen naar verwachting gebruik maken van verschillende geavanceerde technologieën zoals kunstmatige intelligentie, Internet of Things (IoT) en duurzame energiesystemen om met behulp van slimme materialen efficiënter, verbonden systemen te creëren die in staat zijn om te voldoen aan de toenemende vraag naar connectiviteit en duurzaamheid. Maar de ontwikkeling van dit soort infrastructuren kent de nodige uitdagingen.

De rol van infrastructuurbeheerders om de uiteenlopende en vaak concurrerende eisen en vereisten te balanceren is cruciaal. Deze complexiteit onderstreept het belang van strategische besluitvorming bij het ontwerpen van infrastructuur, aangezien deze beslissingen de maatschappelijke uitkomsten kunnen bepalen. Naarmate de verstedelijking toeneemt, wordt verwacht dat infrastructuren van de volgende generatie transport optimaliseren, de realisatie van slimme steden faciliteren en de kwaliteit van leven vergroten. Daarnaast moeten ze veerkrachtig zijn en rampen en cybersecuritydreigingen kunnen weerstaan. Investeringen in infrastructuren kunnen bovendien de internationale concurrentiepositie versterken, innovatie aantrekken en bijdragen aan economische groei. Om aan de behoeften van een technologisch ontwikkelde en onderling verbonden wereld te kunnen voldoen, moet echter zorgvuldig worden gekeken naar de maatschappelijke gevolgen en is een evenwichtige benadering van duurzaamheid, efficiëntie en veerkracht vereist.

Infrastructuur omvat essentiële systemen, waaronder fysieke verbindingen zoals wegen, bruggen en nutsvoorzieningen, maar ook ingewikkelde socio-

technische netwerken zoals telecommunicatienetwerken. Infrastructuren worden van oudsher sectoraal en beheerd, maar het veranderende landschap van maatschappelijke behoeften, milieuvereisten en technologische ontwikkelingen vragen in toenemende mate om erkenning van bestaande en groeiende onderlinge afhankelijkheden tussen infrastructuren. Het erkennen van deze onderlinge afhankelijkheden is cruciaal voor effectief ontwerp, beheer onder verschillende condities inclusief crises en uitval van infrastructuur. Storingen in één infrastructuur kunnen doorwerken in andere infrastructuren. Asset managers die, ondanks dat ze onafhankelijk opereren en hun eigen specifieke manier van werken hebben ontwikkeld, moeten in toenemende mate nauw samenwerken om deze onderling verbonden systemen te ontwerpen en beheren. Deze gezamenlijke aanpak is essentieel voor het ontwerpen en beheren van stabiele en veerkrachtige next generation infrastructuren.

Het ontwerp en beheer van de volgende generatie onderling verbonden infrastructuren brengt tal van complexe uitdagingen met zich mee. Deze omvatten specifieke technische kwesties, zoals betrouwbaarheid en schaalbaarheid van systemen, maar ook omgaan met veiligheidsdreigingen, regelgeving en maatschappelijke gevolgen. Om bijvoorbeeld betrouwbaarheid en veerkracht te garanderen, is een zorgvuldige planning nodig om een veerkrachtige respons op systeemstoringen en het omgaan met onverwacht toegenomen gebruik mogelijk te maken. Bovendien is de integratie van nieuwe, energie-efficiënte oplossingen cruciaal voor het verminderen van de impact op het milieu en de operationele kosten van infrastructuren. Het overwinnen van deze uitdagingen is van fundamenteel belang voor het ontwikkelen van robuuste, veilige en efficiënte infrastructuren. Dit vereist voortdurende samenwerking, uitgebreide risicobeoordelingen en adaptieve ontwerpstrategieën.

Zes grote Nederlandse infrastructuurbeheerders die binnen NGInfra met elkaar samenwerken (Alliander, Havenbedrijf Rotterdam, ProRail, Rijkswaterstaat, Schiphol en Vitens) (h)erkennen deze uitdagingen bij het

ontwerpen van een nieuwe generatie toekomstbestendige infrastructuren en erkennen de noodzaak van een responsieve, gezamenlijke aanpak. Door samenwerking te bevorderen willen deze organisaties robuuste, veilige en efficiënte onderling verbonden infrastructuren creëren die kunnen voldoen aan de veranderende maatschappelijke behoeften. Deze gezamenlijke inspanning vereist aanzienlijke investeringen, innovatie en expertise uit verschillende kennisdisciplines. Schaarste aan middelen en beperkte kennis binnen één organisatie onderstreept de noodzaak van samenwerking tussen verschillende infrastructuureigenaren om de onderling samenhangende en complexe problemen van infrastructuren van de volgende generatie aan te pakken. Deze horizontale vorm van samenwerking leidt tot nieuwe kansen om innovatieve, veerkrachtige oplossingen te realiseren in nieuwe infrastructuurprojecten. De literatuur benadrukt dat de kwaliteit van samenwerking in het huidige versnipperde infrastructuurbeheer voor verbetering vatbaar is. Het creëren en faciliteren van samenwerking tussen infrastructuurorganisaties, met andere woorden, inter-organisatorische samenwerking (IOC), is vereist om de gewenste resultaten en synergie bij de ontwikkeling van infrastructuren van de volgende generatie infrastructuren te kunnen realiseren.

Om samenwerking te stimuleren is de onderzoeksvraag van dit proefschrift: **hoe kan samenwerking tussen infrastructuureigenaren in onderling verbonden infrastructuurprojecten worden gefaciliteerd?**

Dit onderzoek richt zich op infrastructuurprojecten waarin verschillende Nederlandse infrastructuureigenaren samenwerken. In de eerste stap werd vooronderzoek uitgevoerd om inzicht te verkrijgen over samenwerking en gegevensdeling bij cross-infrastructurele projecten. In het bijzonder werd ingezoomd op informatiedeling tijdens de vroege fases van gezamenlijke infrastructuurprojecten. Er werden semigestructureerde interviews afgenomen op zowel organisatie- als projectniveau met respondenten uit de praktijk van verschillende Nederlandse infrastructuurorganisaties. Uit de resultaten blijkt dat

de beschikbaarheid en toegankelijkheid van data in gezamenlijke infrastructurele projecten problematisch is waarin en dat het delen van gegevens fundamentele problemen op het gebied van interorganisatorische samenwerking oproept. De problemen zijn het resultaat van een aantal samenhangende vraagstukken zoals dataschaarste en -toegankelijkheid, verouderde gegevensopslag, verschillende vormen van dataregistratie, gegevensbeheer en datastandaarden, en verschillen in data management beleid. Het delen en gebruiken van data over organisatiegrenzen is echter noodzakelijk om projectdoelen te bereiken bij gezamenlijke infrastructuurprojecten, omdat het gezamenlijke besluitvorming en probleemoplossing vergemakkelijkt. Bovendien stimuleert het delen van data transparantie en verantwoording tussen de deelnemende organisaties, wat kan leiden tot meer vertrouwen en samenwerking. Het maakt ook de inzet van collectieve intelligentie en expertise mogelijk, hetgeen kan leiden tot innovatieve oplossingen die bijdragen aan gewenste projectresultaten. Toen we ons richtten op de status van het delen van data en samenwerking in interorganisatorische infrastructuurprojecten in Nederland, ontdekten we dat het delen van gegevens en samenwerking nauw met elkaar verweven activiteiten zijn. Met andere woorden, het delen van gegevens is essentieel om succesvol samen te werken met andere infrastructuurbeheerders. Omgekeerd stimuleert een samenwerkingsomgeving het effectief delen van gegevens in gezamenlijke infrastructuurprojecten. Dit proefschrift draagt bij aan het ontwerpen en ontwikkelen van samenwerking tussen infrastructuurbeheerders en beoogt daarmee een bijdrage te leveren aan het verbeteren van het delen van data in gezamenlijke infrastructurele projecten in Nederland.

Vooronderzoek identificeerde verschillende uitdagingen die samenwerking tussen medewerkers van infrastructuurbeheerders tijdens gezamenlijke infrastructuurprojecten belemmerde. De belangrijkste uitdagingen van IOC in infrastructuurprojecten werden geïdentificeerd in drie verschillende cross-sectorale infrastructuurprojecten in Nederland.

Factoren die bijdragen aan IOC werden geïdentificeerd door middel van een literatuurstudie en vergeleken met de antwoorden van interviews. Ze werden met behulp van Q-methodologie geanalyseerd zodat een beeld kon worden gevormd van de perspectieven van practitioners. Q-methodologie biedt een benadering om de subjectieve standpunten van respondenten over het onderzochte onderwerp gestructureerd te analyseren en daaruit perspectieven af te leiden. De resultaten van het onderzoek wijzen op het bestaan van twee verschillende perspectieven onder practitioners: een holistisch, doelgericht perspectief en een mensgerichte perspectief. Het holistische, doelgerichte perspectief benadrukt de noodzaak van het stellen van gemeenschappelijke doelen in samenwerkingsprojecten en het belang van (in)formele communicatie tussen medewerkers. Het mensgerichte perspectief geeft prioriteit aan individuele aspecten van samenwerking, zoals respect en vertrouwen tussen de medewerkers om samenwerking tot stand te brengen in cross-sectorale infrastructuurprojecten. De belangrijkste factoren van IOC in beide perspectieven zijn betrokkenheid, respect tussen mensen, een gemeenschappelijk doel en gedeelde visie, en steun van het topmanagement.

Om samenwerking in cross-sectorale infrastructuurprojecten te stimuleren is het noodzakelijk om op de hoogte te zijn van de status van de samenwerking en haar sterke en zwakke punten. De criteria om samenwerking te beoordelen werden geïdentificeerd aan de hand van een literatuurstudie en een serie diepte-interviews met practitioners van infrastructuurbeheerders met ervaring in cross-sectorale infrastructuurprojecten. Op basis van criteria die werden verkregen uit beide dataverzamelingsmethoden werd een beoordelingsinstrument voor interorganisatorische samenwerking (ICAT) ontwikkeld (Tabel II). ICAT onderscheidt twaalf criteria en zesendertig subcriteria om samenwerking te kunnen meten en bij te dragen aan ontwerpen van samenwerking (*ex-ante*). Daarbij wordt een onderscheid gemaakt in drie categorieën: Individueel samenwerkingsvermogen, relationeel samenwerkingsvermogen en organisatorisch samenwerkingsvermogen. ICAT kan ook gebruikt worden om

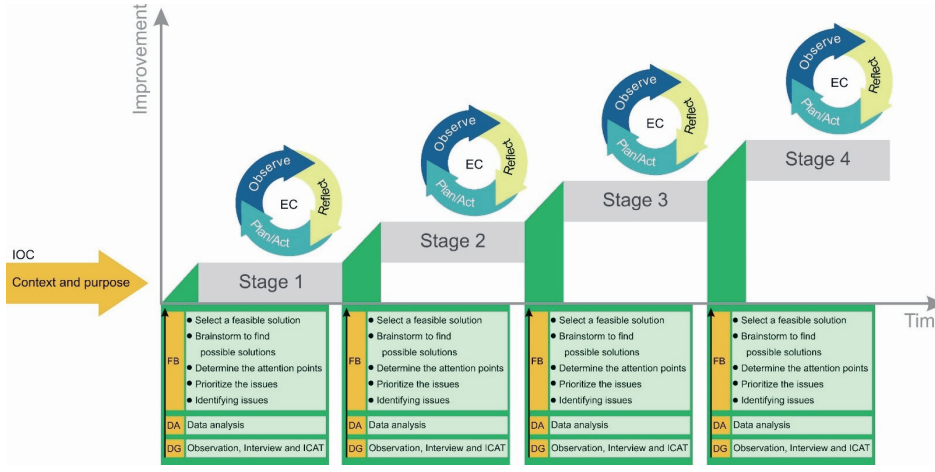
samenwerking tijdens en na afloop van een gezamenlijk infrastructuurproject te beoordelen (*ex-post*). De ICAT stelt practitioners in staat om de status van samenwerking in cross-infrastructurele projecten te monitoren en verbeteren.

Tabel II. Interorganisatorische samenwerkingsbeoordelingstool (ICAT)

(ICC) Individueel samenwerkingsvermogen	i.1	Houding en motivatie
	i.2	Houding ten opzichte van andere deelnemers
	i.3	Vermogen om met anderen te werken
(RCC) Relationeel samenwerkingsvermogen	r.1	Werkklimaat
	r.2	Gedeelde visie
	r.3	Kennis delen
	r.4	Relationship continuity
	r.5	Diversiteit van waarden
(OCC) Organisatorisch samenwerkingsvermogen	o.1	Leiderschap
	o.2	Communicatie
	o.3	Geformaliseerde procedures
	o.4	Verbeterde oriëntatie

Een actie-onderzoek werd uitgevoerd in een Nedelands infrastructuurproject waarin twee infrabeheerders samenwerken op basis van gelijkwaardigheid. Doel van het onderzoek was om een diepgaand begrip te verkrijgen van processen die samenwerking bevorderen. Actieonderzoek biedt de onderzoeker de kans om samen te werken met practitioners tijdens een infrastructuurproject. In dit geval werden wetenschappelijke perspectieven gecombineerd met praktijkkennis om samenwerking te verbeteren. Een proces om samenwerking te verbeteren werd ontworpen, een iteratieve verbeteringscyclus. De cyclus bestond uit meerdere fasen (Zie Figuur II). Elke fase omvat vier stappen: gegevensverzameling (DG), gegevensanalyse (DA), feedback (FB) en een verbetering. Gegevens werden verzameld door observaties, interviews en de ICAT-beoordelingen. De totale

dataverzameling maakte het mogelijk de samenwerkingsstatus te beoordelen en obstakels en problemen voor samenwerking te identificeren. De resultaten van de analyse worden met de practitioners besproken. Vervolgens worden de samenwerkingsproblemen geprioriteerd en wordt gebrainstormd over mogelijke oplossingen om samenwerking te verbeteren. De output van de feedbacksessie (FB) wordt gebruikt voor de iteratieve verbetercyclus. De focus van de iteratieve verbetercycli ligt op de door de practitioners geïdentificeerde prioriteiten. Het voorgestelde proces stelt practitioners in staat om samenwerkingsproblemen in cross sectorale infrastructuurprojecten proactief aan te pakken. Afhankelijk van de aard van de problemen en de geplande acties, kunnen meerdere onderwerpen die samenwerking verbeteren tegelijkertijd worden geadresseerd. In het gezamenlijke infrastructuurproject dat werd onderzocht resulteerde de toepassing van het voorgestelde proces om samenwerking te verbeteren tot een hogere beoordeling van projectmedewerkers op de criteria ‘gedeelde visie’ en ‘communicatie’.

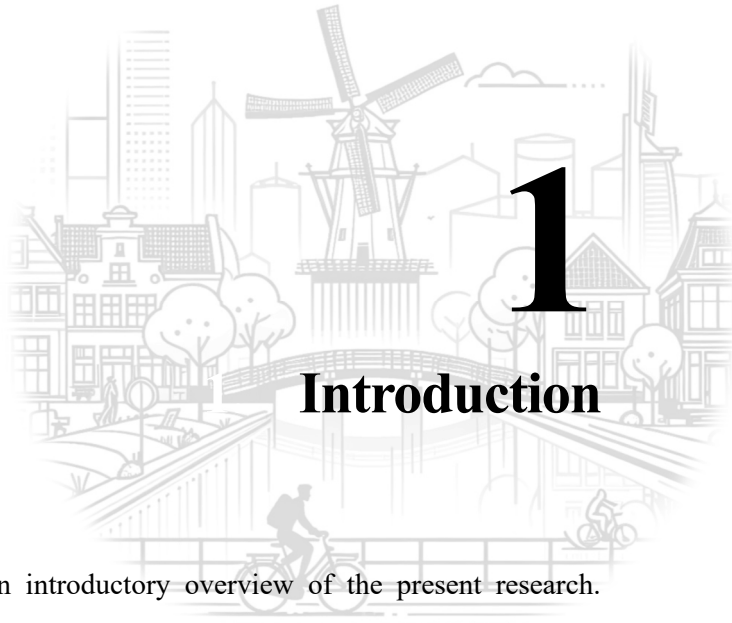


Figuur II. Het IOC-proces dat in dit proefschriftonderzoek werd ontwikkeld. Afhankelijk van de complexiteit van een project kunnen in een fase meerdere onderhoudscycli (EC) worden gedefinieerd. Bovendien kunnen de onderhoudscycli meerdere keren herhaald worden tijdens een fase.

Dit proefschrift focust op ‘horizontale’ samenwerking. Alle factoren die bijdragen aan de totstandkoming van inter-organisatorische samenwerking (IOC) in onderling verbonden infrastructuurprojecten zijn in beeld gebracht. Het identificeren van alle criteria die gebruikt kunnen worden om samenwerking te meten draagt niet alleen bij aan wetenschappelijke kennis over samenwerking, maar kan ook als een instrument voor en door infrastructuurpractitioners worden ingezet om de kwaliteit van een samenwerking te beoordelen. De tool beslaat drie kritieke aspecten van samenwerking en wordt samengevat weergegeven in Tabel II. Door de tool in de praktijk toe te passen konden enkele verbeterpunten worden geïdentificeerd die practitioners kunnen ondersteunen bij het verbeteren van samenwerking (zie Hoofdstuk 6). Door de resultaten van dit onderzoek samen te bundelen, stelt het proefschrift een IOC-verbeteringsproces (IOCF) voor dat toepasbaar is in cross-infrastructurele projecten. Het voorgestelde proces heeft tot doel om practitioners uit te dagen om continu te werken aan het verbeteren van samenwerking tussen infrastructuurorganisaties. Op deze wijze hoopt het onderzoek bij te dragen aan het adresseren van complexe uitdagingen die tijdens samenwerking kunnen ontstaan en die tot doel hebben infrastructuur practitioners te stimuleren om innovatieve oplossingen te ontwikkelen.

Op basis van dit onderzoek worden verschillende aanbevelingen gedaan voor toekomstig onderzoek naar IOC. Toekomstige studies zouden de randvoorwaarden die nodig zijn voor succesvolle IOC op organisatieniveau kunnen bestuderen. Daarbij zouden ze zich met name kunnen richten op het verbeteren van interne processen zoals gegevensbeheer, communicatiekanalen en organisatorisch aanpassingsvermogen. Het ontwikkelen van een toets om te kunnen beoordelen of een infrastructuurorganisatie gereed is om samen te werken zou eveneens waardevol kunnen zijn. Daarnaast kan modelering van de relaties in de projectorganisatie helpen om de relatie tussen factoren die IOC beïnvloeden te onderzoeken. Vooral in onderling verbonden infrastructuurprojecten kunnen inzichten worden ontwikkeld over hun complexe

interacties. Het uitbreiden van de scope van onderzoek naar infrastructuurorganisaties in landen met verschillende culturele achtergronden kan onthullen hoe culturele variaties IOC beïnvloeden en overeenkomsten en verschillen tussen verschillende omgevingen blootleggen. Tot slot biedt de in deze studie ontwikkelde methode die tot doel heeft IOC te verbeteren een basis voor toekomstig onderzoek om best practices voor het verbeteren van samenwerking in verschillende contexten te identificeren.



1 Introduction

This chapter provides an introductory overview of the present research. Focusing on inter-organizational collaboration in interconnected infrastructure projects. The background and significance of the research topic is explained in this chapter. A foundation for understanding the necessity of facilitating collaboration among infrastructure owners is established. The requirements to develop resilient and flexible infrastructures capable of adapting to current and future challenges highlights the critical role of collaborative efforts in interconnected infrastructure projects. This chapter acknowledges the demand for multidisciplinary knowledge and expertise in developing next-generation infrastructures. Moreover, the chapter elucidates the primary objectives and scope of the research, offering a roadmap that guides readers through the subsequent chapters.

1

1.1. Introduction

We live in a rapidly evolving, highly interconnected world, facing increasingly global, complex, and dynamic problems. Global challenges include external issues such as climate change, pandemics, energy transition, and sustainability, which demand new technologies and big-data analysis (Große-Bley & Kostka, 2021; Huang, 2021). The speed and intensity of these challenges and changes are expected to increase in the future, largely affecting the infrastructure construction sector and its ability to adapt to changes (de Oliveira, Bellezoni, Shih, & Bayulken, 2022).

Nowadays, the construction industry including the infrastructure sector provides vital services for society and is an important foundation of future economic growth and societal development (Gardner, 2015; Hatem, Kassem, Ali, & Khoiry, 2022; Ofori, 2015). Developing any nation requires reliable and well-developed infrastructures (Ngowi, Pienaar, Akindele, & Iwisi, 2006). However, in many places around the globe, infrastructures that have been developed post World War II technically and functionally reach the end of their lifetime in the next few years due to degradation, intensive usage, and new regulations concerning environmental issues (Hertogh, Bakker, van der Vlist, & Barneveld, 2018). Therefore, developing, upgrading, and replacing these infrastructures is essential to cope with the new global changes.

Development of resilient and flexible infrastructures is needed to ensure the ability to adapt to current and future changes (Mehvar *et al*., 2021). Due to the increased integrated functionality and mutual dependency on infrastructures, the development of next-generation infrastructures is becoming more complex and requires multidisciplinary knowledge and expertise (NGI, 2019). On one hand, for organizations, it is becoming more and more of a challenge to have sufficient knowledge, experience, and resources to tackle complex problems. On the other hand, strong interdependency between various infrastructures affects each

other's performance. The problems that arise in such interrelated and complex environments cannot be addressed effectively in isolation. Any change in one of the infrastructures affects the other infrastructures (Mehvar *et al*., 2021). The increasing interdependencies among infrastructures also introduce significant risks. However, such interconnections are inevitable in next-generation infrastructure systems. Furthermore, the literature highlights a poor track record in designing, realizing, and operating infrastructures, and indicated that the majority of projects in the infrastructure sector do not finish within budget and/or schedule (Edwards, 2021; Flyvbjerg, 2007; Lo, Zhang, Ye, & Cui, 2022). Therefore, fostering effective collaboration during the early design phase appears crucial to developing robust and resilient infrastructure. Early-stage communication can enable organizations to move beyond isolated decision-making, collaboratively identify potential risks, and integrate mitigation strategies into the design process, ultimately reducing system failures and downtime. To design and develop next-generation infrastructures, stimulating various infrastructure owners to collaborate at the early stage of a project and combining multidisciplinary knowledge, resources, and collaborative skills are deemed to create new opportunities, achieve possible innovative solutions, and realize desirable, resilient infrastructure projects (NGI, 2019).

The design and development of interconnected infrastructures are increasingly reliant on data systems (NGI, 2019). Sharing and using data intelligently leads to smarter capacity utilization and supports the development of new infrastructure (NGI, 2019). Monitoring growing data streams generated by infrastructure organizations is important in the development, maintenance, and operation of the interconnected infrastructure. One of the key changes is the integration of digital technologies into the infrastructure system (Gatti & Chiarella, 2020). Digitization of data not only benefits actors engaged in infrastructure development and operations but also results in more resilient and smarter infrastructures (Gatti & Chiarella, 2020). However, exploiting these

benefits requires the availability and sharing of high-quality data across infrastructure organizations. Collecting the right data can support important and cost-effective decisions to manage infrastructure systems (Gatti & Chiarella, 2020).

Collecting data and sharing them across organizational boundaries and sectors are required to manage complex and interconnected infrastructure projects. These data might not be available within a single infrastructure organization. Hence, fostering collaboration among various infrastructure owners can offer synergistic advantages. Collaboration between infrastructure owners (*i.e.,* horizontal collaboration) results in innovation in dealing with the complex environment by increasing infrastructure organizations' capability and blurring organizational boundaries (Gatti & Chiarella, 2020). Collaborating across organizational boundaries and making use of data generated in various infrastructure organizations support a synergetic workflow and facilitate the development of optimal and/or innovative solutions for the design of next-generation infrastructures.

Collaboration between various infrastructure owners, in other words, inter-organizational collaboration (IOC), provides an opportunity to work jointly towards a common goal and increase interpersonal interaction within inter-organizational teams (Surtees, 2016). This can lead to performance improvement by reducing uncertainty, enabling access to shared resources and enhancing the sharing of data and knowledge across organizational boundaries (Surtees, 2016). The individual organization's interests, minimizing risks, resource diversification, and the gaining of complementary data and competencies motivate organizations to collaborate (Armstrong & Jackson-Smith, 2017; Calamel, Defélix, Picq, & Retour, 2012). However, high fragmentation among the infrastructure organizations and sectors in which they operate causes difficulty in joining organizational forces (Armstrong & Jackson-Smith, 2017; Van Meerkerk, van Buuren, & Edelenbos, 2013). Fragmentation of

organizations in construction projects results in conflicts among participants, ineffective collaborations, and eventually time overruns, waste of resources, rework, and project failures (Ekström, 2017; Ghassemi & Becerik-Gerber, 2011; Lichtig, 2010). Fragmentation can arise from the need for specialization within or across disciplines (Bigo & Negru, 2008; Fellows & Liu, 2012). The fragmentation issue can be overcome by collaborating in an integrated manner across various disciplines and organizations (Faniran, Love, Treloar, & Anumba, 2001). Since each organization is specialized in one or more fields (Vilana & Monroy, 2010), collaboration can benefit involved organizations to exploit the expertise and knowledge of other organizations, leading to a high degree of synergy that results in outcomes that could not have been achieved by working individually (Emmitt & Ruikar, 2013).

Despite the significance of collaboration and its beneficial role in the construction industry, it is often overlooked and poorly fulfilled in practice (Faris, Gaterell, & Hutchinson, 2019; Lu, ElMaraghy, Schuh, & Wilhelm, 2007; Vangen & Huxham, 2005). However, the quality of collaboration between various organizations has an impact on a project's success, and this is particularly so in complex infrastructure projects (Kokkonen & Vaagaasar, 2018). Managing inter-organizational collaboration with multi-partners is challenging and requires further study to identify the challenges and facilitate collaboration processes (Kokkonen & Vaagaasar, 2018; Vangen & Huxham, 2005).

A wide variety of studies in the literature has been conducted on collaboration between infrastructure owners and contractors (Bresnen & Marshall, 2000; Kivilä, Martinsuo, & Vuorinen, 2017; Suprapto, 2016) and collaboration within construction supply chains (Koolwijk, van Oel, Wamelink, & Vrijhoef, 2018; McIvor, Humphreys, & Cadden, 2006). However, in contrast to these so-called vertical forms of collaboration, the horizontal form of collaboration (*i.e.,* collaboration and relationship between various infrastructure owners) has not been thoroughly addressed in literature (Hetemi, Ordieres, & Nuur, 2022;

Sydow & Braun, 2018). This research focuses on facilitating horizontal collaboration between various infrastructure owners to develop and design interconnected infrastructure projects. As part of a successful research proposal, the project initially aimed to investigate data-sharing during inter-organizational projects. Using mutual data, combining and sharing data between various infrastructure owners is indispensable to fulfil collaborative projects. However, availability and making use of data is still a fundamental problem and hinders data sharing in inter-organizational projects, which will be discussed in detail in Chapter 2.

1.1.1. Interconnected infrastructures

Infrastructure refers to the fundamental systems, structures, and facilities that support the functioning and development of a society. This can include physical structures and complex socio-technical systems such as roads, bridges, water supplies, electrical grids, and telecommunications networks (Carhart, Ersoy, Taylor, & Beigi, 2018; Trist, 1981). Infrastructures are often considered the backbone of a society, providing the basic necessities and resources that are essential for its survival, growth, and progress (Grafius, Varga, & Jude, 2020; Luo, Alkhaleel, Liao, & Pascual, 2020). The development and maintenance of infrastructures are crucial for promoting economic stability, improving quality of life, and fostering sustainable growth in societies (Grafius *et al*., 2020; Rinaldi, Peerenboom, & Kelly, 2001).

Traditionally, infrastructures have been designed and managed in isolation from one another (Grafius *et al*., 2020). However, due to changes in societal demand, environmental factors, and technological developments (Grafius *et al*., 2020), infrastructures cannot be managed effectively in isolation and there is a wide range of interdependencies and interconnections among them (*e.g.,* road and railway infrastructure cross waterways) (Carhart & Rosenberg, 2015). It is essential to comprehend the interdependence and interconnection of

infrastructures to design and manage them, and to ensure their resilience against future disruptions (Grafius *et al*., 2020). The interdependence and interconnection between infrastructures exist as a bilateral relationship, with each infrastructure having a mutual impact on the other (Grafius *et al*., 2020; Rinaldi *et al*., 2001). The interconnection of these infrastructures and their operations can result from their spatial proximity, their organizational or governance structure, and their physical, functional, and digital connections (Carhart *et al*., 2018; Rinaldi *et al*., 2001). The strong interconnection between infrastructures presents opportunities for benefits as well as potential sources of risks (Carhart *et al*., 2018). Collaboration and communication of infrastructure owners enable them to exploit opportunities and minimize risks, leading to reduced costs and the provision of additional benefits (Carhart *et al*., 2018; Grafius *et al*., 2020).

Infrastructures are becoming increasingly complex and more ingrained in our society, which can lead to vulnerabilities that amplify the potential of cascading failures (Grafius *et al*., 2020; Hertogh & Westerveld, 2010; Irwin, Schardong, Simonovic, & Nirupama, 2016; Organek, 2017). In such interconnected infrastructures with high complexities, a failure can propagate to other infrastructures, leading to cascades of failures that can cause major breakdowns of service provision (Nan & Sansavini, 2017). Additionally, these infrastructures are typically not centrally managed, involving numerous private and public entities as independent decision-makers responding to changes and technological advancement (Organek, 2017). It is therefore crucial to consider the interdependency and interconnection of infrastructures to manage and possibly mitigate potential failures to facilitate the resilience and stability of these critical systems.

The focus of this research is therefore not directed towards individual infrastructures, but towards interconnected infrastructures that are situated in close proximity to one another and are connected in such a way that changes in

one infrastructure impact the others. This interconnection necessitates close collaboration among infrastructure owners to design and manage the next-generation infrastructures.

1.1.2. Inter-organizational collaboration

Collaboration is a joint activity by two or more organizations with the goal of generating collective benefit by working together rather than separately (Bardach, 1999; Hickey *et al*., 2023; Imperial, 2005). When collaboration emphasizes shared values and goals, participants are enabled to find mutually beneficial ways to work together and achieve greater value than can be accomplished individually (Imperial, 2005; McNamara, 2012; Stout & Keast, 2021a). Collaboration refers to a durable relationship that unites previously separate organizations within a new structure, with a shared commitment to a mutually agreed goal or planning initiative, in which each organization pools their own resources for the shared outcome (Perrault, McClelland, Austin, & Sieppert, 2011). McNamara (2012) identified the differences between collaboration and other forms of working together, such as cooperation and coordination, by means of 10 elements. Table 1.1 indicates the distinction between cooperation, coordination, and collaboration.

Collaboration across organizational boundaries, known as inter-organizational collaboration (IOC) creates a relationship between multiple organizations that involves sharing resources, skills, and knowledge to work together on a project (Löfström, 2010). The combination of efforts and leveraging the collective strengths of the organizations through IOC leads to generating synergies and collaborative advantages (Prentice, Imperial, & Brudney, 2019; Vangen, 2017). IOC is characterized by a lack of a single authoritative leader and instead relies on negotiated rules, resources, and roles (Phillips, Lawrence, & Hardy, 2000). IOC is a temporary activity that is carried out by multidisciplinary teams in order to achieve the best possible solutions and

outcomes (Emmitt & Ruikar, 2013) and is a form of collective action that creates more value than the sum of the contributions of its individual participants (van den Broek & van Veenstra, 2015). In this study, IOC is defined as "an integral process of collaboration based on trust, honesty, and openness in which multidisciplinary teams from various organizations share their resources, such as skills, expertise, and data, to create a synergy that meets their common goal(s)".

Table 1.1. Distinction between cooperation, coordination, and collaboration (McNamara, 2012).

Element	Cooperation	Coordination	Collaboration
Design	Work within existing organizational structures	Centralized control through hierarchical structures	Shared power arrangements
Formality of the agreement	Informal agreement	Formalized agreements	Informal and formal agreements
Organizational Autonomy	Fully autonomous; policies to govern the collective arrangement are not developed	Semi-autonomous; policies to govern the collective arrangement may be developed by higher authorities	Not autonomous; policies to govern the collective arrangement are developed jointly by participants
Key Personnel	Implementation of the partnership occurs at the lowest levels; leaders are not involved	Implementation of the partnership is based on a higher authority; a boundary spanner may be used to foster linkages	Implementation of the partnership is based on the participants; a convener may help bring participants together
Information Sharing	Basic information shared through informal channels	Information is exchanged through more formal channels	Open and frequent communications through formal and informal channels
Decision Making	Independent decision making	Centralized decision making	Participative decision making
Resolution of Issues	Conflicts avoided through independence	A neutral facilitator may help resolve conflicts	Participants work together to resolve conflicts
Resource Allocation	Information is exchanged	Physical and nonphysical resources are exchanged to achieve individual goals	Physical and nonphysical resources are pooled in support of collective goals
Systems Thinking	System integration does not occur	System integration may occur to better achieve individual goals	System integration does occur to better achieve collective goals
Trust	Trust relationships are not required but may develop	Leaders work closely to create relationships based on trust	Trust between participants is needed to sustain relationships

The implementation of inter-organizational collaboration (IOC), which involves the participation of multiple organizations, can be a challenging task. This is primarily due to the potential for conflicts of interests, differences in organizational values, and misalignment of individual goals with the goals of the collaborative project (Kokkonen & Vaagaasar, 2018; Smits & van Marrewijk, 2012). Therefore, it is crucial to facilitate the collaborative process to design and develop next-generation infrastructures. This requires identifying and addressing potential issues early on and implementing strategies to mitigate them. Additionally, effective communication, trust-building, and a clear understanding of each organization's goals and values are key elements in facilitating the process of inter-organizational collaboration (Rothouse, 2020).

1.2. Research objective and research question(s)

The objective of this research is to facilitate collaboration between various infrastructure owners to design an interconnected infrastructure project. Based on this objective, the main research question is expressed as follows:

How can collaboration between infrastructure owners in interconnected infrastructure projects be facilitated?

To answer the main research question, the following sub-questions are addressed:

Q1. What is the status of inter-organizational infrastructure projects (regarding collaboration and data sharing)?
Q2. What are key challenges of inter-organizational collaboration in interconnected infrastructure projects?
Q3. What factors influence inter-organizational collaboration in interconnected infrastructure projects?
Q4. How can infrastructure practitioners assess the status of inter-organizational collaboration?

Q5. How can the process of inter-organizational collaboration in interconnected infrastructure projects be facilitated?

1.3. Research approach

Research approaches are generally categorized into three types: qualitative, quantitative, and mixed-method research. Quantitative research is relevant to phenomena that can be measured on the basis of quantity or amount (Kothari, 2004). It is applicable to test objective theories by examining the relationship among variables and it is linked to numbered data, statistical analysis, statistical interpretation and measuring the objective facts. Collecting data in quantitative research is more structured and rigid to ensure accuracy in quantitative analysis (Creswell & Creswell, 2022; Kothari, 2004).

Qualitative research focuses on understanding and exploring perceptions, attitudes, beliefs and behavior of individuals or groups (Creswell & Creswell, 2022; Kothari, 2004). Qualitative methods entail, for instance, direct observation, open-ended questions (qualitative interview questions), interpretation of the meaning of the data and subjective assessment of attitudes (Creswell & Creswell, 2022; Kothari, 2004). Qualitative data rely on human interpretation and evaluation and cannot be measured in a rigorous and standard way (Kothari, 2004; Walliman, 2017).

The third approach is mixed-methods research, which is recognized as a key element in the improvement of social science (Gorard & Taylor, 2004). This approach combines both quantitative and qualitative research methods and techniques and includes both numeric and text information (Creswell & Creswell, 2022). According to Johnson, Onwuegbuzie, and Turner (2007), mixed-methods research can be defined as "*the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study*". Applying

mixed-methods research can benefit from the strengths of either qualitative or quantitative approaches.

To fulfil the objective of this dissertation and investigate the status of collaboration in interconnected infrastructure projects to facilitate it, exploring the infrastructure practitioners' perceptions and direct observation of their working attitude in inter-organizational collaboration are required. Therefore, this dissertation predominantly follows the qualitative research approach. The main research approaches to answer each sub-questions of this research and the research outline are shown in Figure 1.1.

Chapter 2 reports on the execution of qualitative research that includes a literature review and exploratory interviews with practitioners involved in interconnected infrastructure projects. A literature review was performed to highlight the state-of-the-art of collaboration and data sharing, primarily in inter-organizational collaborative projects, and to identify which factors facilitate or contribute to collaboration and data sharing. Moreover, exploratory interviews with practitioners involved in interconnected infrastructure projects were conducted to investigate the perceptions of practitioners on the current state of collaboration and data sharing in inter-organizational infrastructure projects. Integrating the perspectives of practitioners and the literature data, Chapter 2 addresses the first research question and presents a list of factors to facilitate collaboration, providing inputs for Chapter 4.

The outcomes of Chapter 2 showed that infrastructure practitioners encounter various challenges during IOC. Identifying the key challenges of IOC can be beneficial in facilitating collaboration. To this end, Chapter 3 reports on qualitative research that was conducted to investigate the key challenges of IOC subjectively through performing semi-structured interviews with infrastructure practitioners involved in three case studies. These cases are a sample of inter-organizational projects where various infrastructure owners collaborate.

Chapter 3 answers the second research question and provides insight for the researcher and practitioners to recognize the potential challenges during a collaborative project, assisting the researcher in this regard while performing action research in Chapter 6.

In Chapter 4, a list of factors facilitating IOC is identified through three sources: a literature study, exploratory interviews with interconnected infrastructure practitioners (Chapter 2), and a single case study of an interconnected infrastructure in the Netherlands. Q-methodology (combining both qualitative and quantitative methods) is conducted to sort out the identified factors to gain an understanding of the infrastructure practitioners' perspectives on these factors. The quantitative part of Q-methodology includes the use of statistical techniques to analyze the results of the Q-sort. The qualitative part of Q-methodology involves the interpretation and understanding of the participants' Q-sort by conducting follow-up interviews with the participants. To answer the third research question, the list of identified factors and the perspectives of practitioners on them are discussed in this chapter. The information provided in Chapter 4, assists the researcher in establishing a collaborative environment within an interconnected infrastructure project in Chapter 6.

Chapter 5 provides the criteria of IOC to assess the status of collaboration, particularly the strengths and weaknesses, in interconnected infrastructure projects. The assessment criteria are identified through performing qualitative research including a systematic literature review and in-depth semi-structured interviews with the infrastructure practitioners. The initial conceptual assessment tool was formulated in the first step (literature study) and is developed and refined based on the practitioners' perspectives (in-depth interviews) in the second step, which aims to address the fourth research question. The assessment tool, as developed in this chapter, is applied in Chapter

6 to evaluate collaboration, and to identify the hindering issues present during a collaborative project.

The knowledge gained in the previous chapters provides the foundation to study the process of IOC in Chapter 6. Action research, a methodology that actively engages both researcher and practitioners in the research process, is employed in this study. This approach combines both quantitative and qualitative techniques to provide a comprehensive understanding of collaboration. While the majority of the research is qualitative, it can also include quantitative data collection and analysis to supplement the qualitative findings. The qualitative component of this research includes data collection through observation and interviews with the participants. Assessing IOC utilizing the assessment tool developed in Chapter 5 and its analysis is the quantitative part of action research. By conducting action research, Chapter 6 describes the development of a collaboration facilitation process (IOCF) to answer the fifth research question.

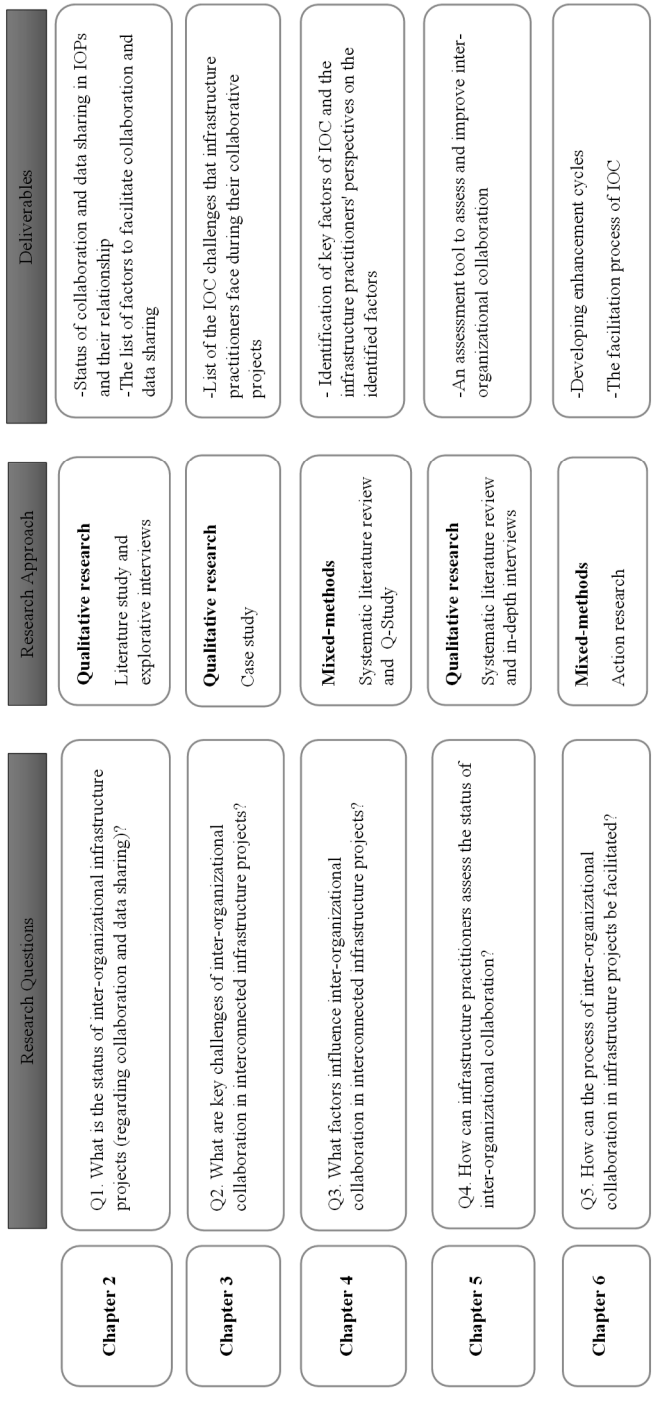


Figure 1.1. The research approach and the research outline followed in the present work.

1.4. Outline of the dissertation

This dissertation is structured into seven chapters. Each sub-question is studied and answered separately in Chapters 2, 3, 4, 5, and 6. Chapter 7 discusses all findings and answers to the main research question.

Chapter 2 (Nezami, de Bruijne, Hertogh, & Bakker, 2022a) describes the status of collaboration and data sharing in inter-organizational infrastructure projects by performing preliminary research at the organizational level and project level in the infrastructure sector in The Netherlands.

Chapter 3 (Nezami, de Bruijne, Hertogh, & Bakker, 2022b) presents the key challenges of IOC in interconnected infrastructure projects by performing semi-structured interviews in three cases in the Netherlands. The cases examined are representative of interconnected infrastructure projects undertaken by different infrastructure organizations (such as road, rail, aviation, water, and energy) in the Netherlands. Through the case studies, the possible challenges and issues regarding IOC that practitioners face in collaborative infrastructure projects are explored and described in this chapter.

Chapter 4 (Nezami, de Bruijne, Hertogh, & Bakker, 2023) identifies the factors that affect IOC in interconnected infrastructure projects through performing literature study and Q-study. The infrastructure practitioners' perspectives on IOC factors are discussed by performing a Q-study, resulting in two perspectives: a "holistic, goal-oriented" perspective, and a more "people-oriented" perspective. The factors of collaboration that have been identified are discussed from these two perspectives.

Since each infrastructure collaborative project is unique with its own characteristics and challenges, the assessment of the status of IOC is essential to be able to manage and improve a collaborative project. Therefore, Chapter 5 (Nezami, de Bruijne, Hertogh, & Bakker, 2024) identifies the assessment criteria

to propose a tool for assessing the status of IOC in interconnected infrastructure projects.

To gain a deeper understanding of the processes of inter-organizational collaboration and to facilitate it, an action research study was conducted on one of the interdependent infrastructure projects in the Netherlands. By utilizing the action research method, the knowledge gained in previous chapters can be applied in practice. Chapter 6 explains the action research process and the development of a facilitation process for IOC.

Chapter 7 describes the findings of the whole dissertation and provides general conclusions and recommendations.

1

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2

Collaboration and Data Sharing in Inter-organizational Infrastructure Construction Projects[1]

A close collaboration between infrastructure owners is crucial to address challenges in the design and execution of next-generation infrastructure projects for sustainable development. Managing and sharing data among parties involved in infrastructure projects, particularly the data required at the early stages of a project to design and develop an interconnected infrastructure project, appear to play a critical role in inter-organizational collaboration (IOC), but are often overlooked. In the present work, the status of collaboration and data sharing between infrastructure owners in inter-organizational infrastructure projects is studied to enhance our understanding of the relationship between collaboration and data sharing in horizontal IOCs. Explorative semi-structured interviews with practitioners were conducted at organizational and project levels in the infrastructure sectors in The Netherlands. The outcomes revealed that the theoretical benefits of IOC are not realized in practice and that managing and sharing data between infrastructure owners in inter-organizational projects (IOP) face many challenges. The findings suggest that collaboration and data sharing are interrelated in horizontal IOCs and are deemed crucial for the execution of IOPs. The findings of the present study demonstrate the importance of the bilateral relationship between effective collaboration and data sharing and provide an enhanced insight into horizontal forms of IOC and practices of next-generation infrastructure development.

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2.1. Introduction

Infrastructures form a specific subset of the construction industry and are a crucial prerequisite for economic growth and societal and community development. Societal and technological developments force infrastructures to adapt and cope with additional complexity and flexibility (Hertogh & Bakker, 2016). Moreover, meeting environmental policies requires that infrastructures be resilient and sustainable. Infrastructures should be flexible enough to meet expected and emergent short- and long-term challenges and capable of adapting to constraints and opportunities resulting from trends (population growth, technology development, climate change) and policies (energy transition and environmental policies). However, sustainable development in an environment that is characterized by unpredictable rapid changes is one of the greatest socio-technical challenges that human beings currently face. Industries, such as the construction industry, have to change fundamentally and become more dynamic and adaptive to cope with uncertainties in technology, development processes, and budgets (Chan, Scott, & Chan, 2004). The realization of next-generation infrastructure projects in such a complex and dynamic environment requires bringing together various disciplines to develop new, detailed and integrated analyses and solutions to address current challenges and avoid or mitigate future problems (Sauvé, Bernard, & Sloan, 2016).

The design, development and implementation of sustainable and resilient infrastructures require new ideas, business models, and multidisciplinary knowledge, which generally cannot be realized at an organizational level because infrastructures are often interconnected, share interfaces and their performance depends on one another (Newell & Swan, 2000; Rinaldi, Peerenboom, & Kelly, 2001). Inter-organizational projects (IOPs) offer opportunities for organizations to benefit from additional resources that are available in other organizations, such as complementary skills, knowledge and facilities (Hetemi *et al*., 2022; Stout & Keast, 2021b). During IOPs, experts from different organizations can

collaborate, think differently, and look across their organizational boundaries and limitations. Being involved in IOPs, organizations work collaboratively and synergistically to acquire state-of-the-art knowledge, technology, and resources (Hetemi *et al*., 2022).

The collaboration of different organizations during IOPs leads to sharing risks and responsibilities, which in turn can enhance the ability of organizations to respond adequately to new challenges and demands (Diirr, Cappelli, Oliveira, Santos, & Borges, 2022; van Fenema, Keers, & Zijm, 2014). Inter-organizational collaboration (IOC) supports the development and realization of IOPs for which multidisciplinary data and knowledge are essential (Alshawi & Faraj, 2002; Jassawalla & Sashittal, 1998). IOC can facilitate the communication and exchange of data across organizational boundaries by creating an open working relationship among participants (Baiden, Price, & Dainty, 2006). IOC is also aligned with new design approaches that stress the integration of organizations with various perspectives and expertise to deal with challenges in complex dynamic environments (Tichkiewitch & Brissaud, 2004). However, the results of IOC assessments indicate high rates of failure and dissatisfaction in practice (Madhok & Tallman, 1998; Thomson & Perry, 2006). Previous studies suggest poor data sharing in infrastructure projects as a critical element that can adversely affect the collaboration of project parties (Tichkiewitch & Brissaud, 2004). The design, development, and implementation of infrastructures strongly rely on data to deliver services at a desirable level of quality (Caldeira, Monteiro, & Simões, 2010; Economics, 2012). Sharing data between infrastructure organizations supports the completion of IOPs within time and budget constraints (Singhvi & Terk, 2003; van den Broek & van Veenstra, 2015). The flow of data across organizational boundaries is considered important for the realization of IOPs (Khan, Flanagan, & Lu, 2016). Thus, IOC and data sharing are considered to positively contribute to inter-organizational infrastructure project goals.

The objective of the present study is to better understand the status of horizontal IOC, data sharing, and their relationship in inter-organizational infrastructure projects. To obtain this level of understanding, a literature study was conducted, providing state-of-the-art knowledge on horizontal IOC and data sharing (Section 2.2). Section 2.3 explains the research methodology, and Section 2.4 provides the results of an in-depth investigation of the perception of practitioners about the status of horizontal IOC and data sharing in inter-organizational infrastructure projects. The discussion and conclusion of the research are presented in Sections 2.5 and 2.6, respectively.

2.2. Literature review

2.2.1. Inter-organizational collaboration

Collaboration is derived from the Latin word "*collaborare*", meaning "work with" (Harper, 2001). Wilkinson (2005) defines collaboration as a "*creative process undertaken by two or more interested individuals, sharing their collective skills, expertise, understanding, and knowledge in an atmosphere of openness, honesty, trust, and mutual respect to jointly deliver the best solution that meets their common goal*". Collaboration generates an opportunity to solve complex and inter-disciplinary problems that might not be achievable otherwise in disaffiliation and can stimulate a search for finding (new) solutions to fulfil project goals (Walker & Lloyd-Walker, 2016). Close collaboration in design and development reduces lead times and improves product quality (Meijer, Voûte, & Tomiyama, 2004). Collaboration also emphasizes the importance of people and social relationships, such as trust and commitment (Burgess, Singh, & Koroglu, 2006). Collaboration is generally beneficial when a variety of knowledge and experiences is required to realize a complex problem and jointly work to come up with solutions (Feast, 2012).

In the literature, collaboration is characterized by several features. First, collaboration engages organizations and interested individuals with a stake in the

outcomes (Healey, 1997; Innes & Booher, 1999). Second, collaboration requires a commitment of parties to solve problems (Gray, 1990; Selin & Chevez, 1995). Third, collaboration involves participants in an intensive and creative process resulting in creative solutions which increase the possibility of acceptance (Gray, 1990; Innes & Booher, 1999). Finally, collaboration contributes to achieving a consensus on issues, aims, and proposed actions (Innes & Booher, 1999).

Collaboration across organizations, also known as IOC, is considered indispensable to deal with complexity in infrastructure projects (van Marrewijk & Smits, 2016) and to develop interconnected infrastructures. Phillips *et al*. (2000) describe IOC as a collaborative relationship without a single legitimate authority but with discursive legitimacy or negotiated rules, resources, and roles. Phillips *et al*. (2000) define IOC as a "*cooperative relationship among organizations that relies on neither market nor hierarchical mechanisms of control"*. Armstrong and Jackson-Smith (2017) define IOC as "*the coming together, deliberation, and agreement between two or more organizations that lead to change*". Emmitt and Ruikar (2013) consider IOC as a temporary activity and state that IOC is the product of multidisciplinary and multi-skilled teams which share their resources, skills, data and knowledge to engage in collaborative practices in projects to achieve synergy, the best possible solutions, and the desired outcomes. IOC can thus be described as a form of collective action: a social organization that creates more value than the sum of its individual participants (van den Broek & van Veenstra, 2015). Based on these insights, an IOC is defined here as "an integral process of collaboration based on trust, honesty, and openness in which multidisciplinary teams from various organizations share their resources, such as skills, expertise, and data, to create a synergy that meets their common goal(s) and thereby delivers the best possible solution".

Complex construction projects, such as interconnected infrastructure projects, cannot be realized by a single individual or organization because of

limited resources, capacity, and data. The scarcity of resources is often the dominant motivation to engage in an IOC (Kożuch & Sienkiewicz-Małyjurek, 2016; Oliver, 1990; Thompson, 2003). IOC provides a framework within which participants feed resources, such as data, funding, competencies and work methods, into a collaborative project (Löfström, 2010). IOC offers benefits such as new knowledge (*i.e.,* learning from collaboration) (Anand & Khanna, 2000; Larsson, Bengtsson, Henriksson, & Sparks, 1998); efficiency, from the pooling of resources; and product or service improvement (Lowndes & Skelcher, 1998). The collaboration of several organizations in a project enables practitioners to exploit the expertise and data from these different organizations to obtain mutual benefits (Hardy, Phillips, & Lawrence, 2003; Surtees, 2016). During an IOC, independent organizations and individuals collaborate to seek collective goals rather than individual ones (Provan & Kenis, 2008). IOC also provides an opportunity to improve practices via innovative approaches and solutions developed by all participants involved in a project (Dodgson, 1993; Greer, 2017; Lawrence, Hardy, & Phillips, 2002). However, the implementation of IOC is challenging in practice due to existing differences among organizations regarding their aims, resources, language, and culture, which hinder the reconciliation of individual and collaborative interests (Thomson & Perry, 2006; Yang & Lemaire, 2022). The quality of a collaborative project depends on the quality of interaction between organizations and individuals and the effectiveness of their relationships during the collaboration. Emmitt and Ruikar (2013) emphasize the importance of factors related to collaboration: such as the level of integration in the project team, equality, communication, development of technologies for data sharing among collaborators, and shared decision-making. Phillips *et al*. (2000) argue that establishing collaborative politics and agreements is one of the main challenges for IOC. The literature, thus, presumes that collaborative challenges hinder IOC (Yang & Lemaire, 2022), leading to fewer collaborations (Thomson & Perry, 2006). Further studies are needed to

explore possible solutions to facilitate the implementation of IOC and enhance its efficacy in practice.

IOC has been studied in different contexts in the infrastructure industry. Previous studies addressed the collaboration and relationships between infrastructure owners and contractors (Bresnen & Marshall, 2000; Suprapto, Bakker, & Mooi, 2015). Furthermore, collaboration has been widely studied in infrastructure supply chains (Koolwijk *et al*., 2018; McIvor *et al*., 2006) and between infrastructure owners, contractors, and design teams (Smyth & Pryke, 2008). However, despite the fact that IOC between different infrastructure owners is deemed essential for infrastructure project success, this more or less "horizontal" rather than "vertical" form of collaboration has not been thoroughly addressed in literature (Hetemi *et al*., 2022; Sydow & Braun, 2018). Further studies are, thus, needed to improve our insight into horizontal IOC in inter-organizational infrastructure projects. It is acknowledged that IOC can facilitate searching for new solutions for emerging challenges in the design and implementation of interconnected infrastructures. To realize these solutions, organizations desire access to multidisciplinary data beyond their organizational boundaries. Therefore, managing and sharing data in inter-organizational projects constitute an important dimension of IOC.

2.2.2. Data sharing

The word "data" originates from Latin and literally means "*something given*" (Tett, 2018). Literature on data sharing identifies three key concepts: data, knowledge, and information. Abdelsayed and Navon (1999) recognize data as facts that are obtained through practice and observation, and knowledge as a collection of data to be used in the future. They state that information represents either data or knowledge for any specific use. Den Otter and Prins (2002) define data as "*abstract, formal, sometimes symbolic entities like elementary facts, letters and numbers*". Zins (2007) considers data as raw material: the building

blocks of information. Data are collected as facts and statistics, which form the basis for referencing, analysis, and calculations. Data become information after they have been interpreted and analyzed, which in turn supports decision-making (Cooper, 2016; Rasmus, 2018). As multidisciplinary data, information, and knowledge are required to design, develop, and implement interconnected infrastructures, data, in the present study, is assumed as an umbrella term that covers data, information, and knowledge.

Data are required in all projects to resolve design and development problems during different stages of project execution (Rauniar, Rawski, Morgan, & Mishra, 2019). Similarly, data are needed during a construction project—from the concept phase to the execution phase (Chen & Kamara, 2008). Large-scale infrastructures strongly rely on data to deliver their services at a desirable level of quality (Caldeira *et al*., 2010) and for the satisfactory completion of projects (van den Broek & van Veenstra, 2015). Various types of data are required in the construction industry to support the design and development of sustainable infrastructures (Higgin & Jessop, 2013; Khan *et al*., 2016). Generating, collecting, managing, and analyzing data are among the core management tasks, which typically take up to 70% of the management's time (Fisher & Yin, 1992). Due to the workload and time constraints in projects, managers prefer to focus on the main project tasks rather than data management (Karagoz, Whiteside, & Korthaus, 2020; Riege, 2005), which can lead to a lack of data after completing collaborative projects. Moreover, designers usually prefer to talk to one another to obtain data, mainly because retrieving data from documents is generally not straightforward, which ultimately results in a considerable level of design data loss (Tichkiewitch & Brissaud, 2004). Organizations need to establish coordination and control over data to facilitate data sharing (van den Broek & van Veenstra, 2015).

Data sharing is often challenging in cross-functional teams, even within a single organization (Bai, Feng, Yue, & Feng, 2017). Despite the well-established

role of data in project success, many challenges persist in data sharing among organizations (van den Broek & van Veenstra, 2015). The construction industry—of which infrastructures are a distinctive part—is characterized by intensive data processing and the exchange of data between project partners has always been a challenge (Abdelsayed & Navon, 1999). Data sharing is mainly restricted due to hierarchies, power relations, and confidentiality concerns (Tichkiewitch & Brissaud, 2004). Since data are valuable, sharing data across organizations can jeopardize the position of an organization, resulting in a tendency to hoard data (Riege, 2005; Yang & Maxwell, 2011). Riege (2005) identifies various barriers to data sharing between organizations including time limitations, cultural differences, lack of communication (which hinder the interaction of involved parties), lack of trust and a proper platform/resource to support data sharing. However, establishing a collaborative environment and close collaboration among parties can overcome barriers to data sharing and knowledge hoarding (Karagoz *et al*., 2020). A collaborative environment and the provision of informal and formal platforms to interact during a collaborative project not only results in data sharing but also enhances opportunities to create new data and knowledge among participants (Riege, 2005).

One of the challenges of executing a project is that data are often not available or easily accessible in a timely fashion (Titus & Bröchner, 2005), which can cause rework, dispute, and delay (Tichkiewitch & Brissaud, 2004). Chen and Kamara (2008) studied data management in construction sites and concluded that data are generally deficient in construction projects. Moreover, effective utilization of data is a demanding task that few organizations have mastered (Gueli, 2008). In some cases, data can be available rapidly; however, they are often complex, and the capability of their correct interpretation and utilization discloses their value more than just the act of collecting them (Deakin-Crick, Huang, Godfrey, Taylor, & Carhart, 2018). Uncertainty and imprecision of data degrades their quality and value (Titus & Bröchner, 2005). To analyze the value

of data, Titus and Bröchner (2005) proposed three factors: quality of the received data, timeliness of receiving data, and cost-effectiveness of obtaining data. The mentioned factors can be optimized to achieve effective decision-making in a project with multiple actors (Titus & Bröchner, 2005). Additionally, data need to be managed, standardized, and integrated to yield value and establish an effective collaboration of various actors as well as organizations (Kurapati, Kourounioti, Lukosch, Tavasszy, & Verbraeck, 2018; Titus & Bröchner, 2005), which is a challenge for data sharing (Khan *et al*., 2016).

A lack of data disrupts decision-making in construction projects (Izam Ibrahim, Costello, & Wilkinson, 2013). Data in the construction industry have a considerable influence on the decision-making process and solution-finding (Chen & Kamara, 2008). The importance of data sharing to improve the performance of construction projects has been extensively underlined in the literature (Chen & Kamara, 2008). However, participants in construction projects are often unwilling to share data, which might be due to a lack of sufficient trust between them caused by the temporary nature of the projects (Briscoe & Dainty, 2005; Cheng, Law, Bjornsson, Jones, & Sriram, 2010). Consequently, appropriate solutions for data management in construction projects are yet to be explored (Chen & Kamara, 2008).

Data sharing across organizational boundaries is the backbone of successful projects with better performance (Khan *et al*., 2016). According to Jensen, Bjørn-Andersen, and Vatrapu (2014), providing a common integrated flow of data with transparency and improving data sharing can result in project cost reduction. To this end, to avoid extra costs associated with rework caused by inappropriate decisions and to enhance collaboration in multidisciplinary projects, efficient data management between organizations would be an effective solution (Tichkiewitch & Brissaud, 2004; Titus & Bröchner, 2005). Data sharing is, thus, recognized as one of the major factors that allow collaboration between infrastructure managers (Kurapati *et al*., 2018). To clarify this perspective,

Senescu, Aranda-Mena, and Haymaker (2012) recognized three types of data sharing: (1) within project, (2) between projects, and (3) across firms or industries. All of these routes for data sharing should be properly paved to serve efficient mobility of data.

Data sharing has been studied in different fields of science (Abdelsayed & Navon, 1999; Lee & Yu, 2012). The concepts of data sharing and management have also been studied in the project management arena (Park & Lee, 2014; Pee, Kankanhalli, & Kim, 2010; Rauniar *et al*., 2019; Ståhle, Ahola, & Martinsuo, 2019). However, data sharing in inter-organizational infrastructure construction projects has not received much attention in literature. Thus, data sharing and factors contributing to data sharing are considered in this study. Based on the literature review presented here, collaboration with other organizations and data sharing between organizations are essential to obtain innovative solutions and fulfill mutual goals in infrastructure projects. The present study investigates the status of collaboration and data sharing in inter-organizational infrastructure projects, describes the perceptions of practitioners on IOC and data sharing, and explains the relationship between collaboration and data sharing in IOPs.

2.3. Research methodology

To understand the status of collaboration and data sharing and to investigate the effect of data sharing on collaboration and vice versa in inter-organizational infrastructure projects in the Netherlands, preliminary research was conducted at the organizational and project level. To fulfil the objective of this research, the qualitative-interpretive approach was chosen. The interpretive approach assumes that social reality is formed by human experiences and social contexts rather than objective reality (Yanow & Schwartz-Shea, 2014).

Data were collected by conducting semi-structured interviews to gain the practitioners' insights into how collaboration and data are organized and if they influence each other in IOPs. Nine interviews were conducted at the

organizational level in six public infrastructure organizations in the Netherlands, which are providers of critical infrastructure networks such as aviation, rail, road, water, and energy. The respondents were selected based on their relevant experience in interconnected infrastructure projects. Additionally, twelve interviews were performed at the project level in two infrastructure construction projects in the Netherlands. The respondents had key roles in the projects. The overview of the respondents is shown in Table 2.1.

All interviews in the study took approximately one hour. Three main themes were covered in the interviews: collaboration, the inter-organizational context, and data sharing. The interviews were recorded and transcribed. The factors of collaboration and data sharing were extracted by assigning codes to relevant themes (collaboration, data sharing). The results of the interviews, including the factors of collaboration and data sharing, are elaborated in Section 2.4.

Table 2.1. The overview of the respondents based on their function.

Organization/Project		**Function**
Organization	Respondent 1	Senior asset manager
	Respondent 2	Adviser
	Respondent 3	Project engineer
	Respondent 4	Developer
	Respondent 5	Senior manager
	Respondent 6	Project manager
	Respondent 7	Strategy Director
	Respondent 8	Project Director
	Respondent 9	Senior manager
Project	Respondent 10	Developer
	Respondent 11	Project Executive
	Respondent 12	Developer
	Respondent 13	Adviser
	Respondent 14	Project manager
	Respondent 15	Adviser
	Respondent 16	Project engineer
	Respondent 17	Project leader
	Respondent 18	Senior adviser
	Respondent 19	Project leader
	Respondent 20	Adviser
	Respondent 21	Project Manager

2.4. Results

This section elaborates the status of collaboration and data sharing in IOPs and their effect on each other.

2.4.1. The status of collaboration in IOPs and whether data sharing facilitates collaboration in IOPs

In this section, the interpretation of respondents on collaboration, the status of collaboration in IOPs, and the relationship between collaboration and data sharing are explored. In summary, definitions provided by the respondents for collaboration read as "*deciding and performing tasks together*", "*sharing the benefits fairly*", "*having mutual goals and trying to achieve them together*", "*being open to each other and keeping in contact with parties to have an open communication*", and "*understand each other's perspectives and jointly looking for shared interest*".

Working together, openness, and data sharing between various actors in IOPs are considered important aspects of collaboration, resulting in mutual understanding and goal alignment. Some respondents distinguished collaboration from other forms of relationships. A project manager mentioned that there is a difference between collaboration and transactional relationships. The latter one was based on "*if you give me this, I will give you that*" and not a true form of collaboration.

The respondents mentioned that there is limited space and there are limited resources to build new infrastructure or develop the current infrastructures, so these issues require close collaboration of various infrastructure owners. Furthermore, according to the interviews, a lot of rework happens in infrastructure construction projects. A senior manager argued that by bringing different organizations together and conducting part of the activities just once (*e.g.,* digging the ground once), the process could be both facilitated and accelerated, saving a considerable amount of associated costs. This respondent

also adds: "*the government should have a role in saying; hey guys! Don't get more space! You should do the project smarter with each other; you should coordinate it better together*".

However, the interviews revealed that collaboration among various infrastructure owners is lacking "*we mainly share our requirements with the other infrastructure owner, and they lead and perform an interconnected infrastructure project and only ask for approval, but this is not a real collaboration*". A project leader reported that there is no intensive collaboration among infrastructure owners: "*we have met other infrastructure parties in occasional workshops or meetings, however, regular meetings should be organized to jointly work on a project, which is usually not happening*". Meeting the requirements and functional specifications of other infrastructure owners without jointly working with them is challenging and lengthens the project's duration. In addition, an adviser stated that each organization involved in the project has its own interests and requirements that should align with others. In this line of reasoning, he proposed to make a joint collaboration between different infrastructure owners to not only present the main interests and requirements but also to facilitate understanding the common interests which entail close contact with each other.

However, according to the respondents, there are silos between infrastructure owners "*silos can be seen everywhere as a large wall that is further growing and people think in a siloed hierarchy*". A project manager argued that silos are not limited to various infrastructure owners, but also exist between different departments of an infrastructure organization, which hinders efficient collaboration within an organization. The silos produce isolated intra-organizational attempts to design and manage infrastructure projects. However, the infrastructures nowadays are more interconnected and are placed in each other's neighborhoods, as quoted by a project executive: "*if you make a design for your infrastructure, you should also look around the neighborhood of your*

environment and invite the relevant infrastructure owners to collaborate and to integrate their needs in the design", which leads to synergies, improved solutions, cost and time reductions for the project, and resilient infrastructure for the future. According to the interviewees, silo effects, a lack of communication, and a lack of close collaboration among infrastructure owners hinder the integrated design of infrastructures.

To address this issue, a project engineer stated that the flow of data as a chain could connect the components of collaborative works and eliminate the silos. A director added that sharing data in a proper way and making it available to collaborators and decision-makers of the involved infrastructure owners can not only overcome silos, but also facilitate IOC; however, this has not yet happened in practice.

The respondents believed that the silo effect and lack of joint collaboration between various infrastructure owners was rooted in the existence of different work attitudes, work processes, and standards of data sharing. An adviser mentioned that "*we should establish a collaboration agreement with other infrastructure owners on how to collaborate and how to structure data*". An adviser stated that a collaborative agreement provides a baseline for desired collaboration, mutual trust, and balance among parties, and mentioned that "*one party may expect everything without being asked for anything during a collaboration*". Establishing a collaboration agreement prevents opportunistic behaviors during IOCs. A senior manager advocated the establishment of collaboration agreements and emphasized the need for a role to assist in creating such an agreement: "*collaborative parties need someone that establishes an agreement. It does not need to be a leader but someone without bias*".

It is understood from the interviews that a collaborative agreement is one of the essential factors for IOC. In the opinion of a senior manager, such an agreement should be made before the collaboration starts to balance the expenses

and benefits attained from a collaborative project. He believed that the lack of such an agreement can demotivate collaborative parties and can even disrupt a collaboration, because under certain circumstances a partner might encounter a problem in a collaborative project that cannot be solved alone, and this can terminate the collaboration.

The respondents also believed that knowing each other, having good discussions about project goals, and having social meetings and informal chats can facilitate the relationship between the parties. Collectively, a list of factors that affect collaboration was identified based on the interviews, and it is presented in Figure 2.1.

Figure 2.1 shows that common goals, teamwork, openness, and interpersonal understanding were mentioned more frequently by respondents as factors facilitating collaboration. It is important to achieve “common goals and shared vision” with people from various organizations that may have different perspectives during collaboration. As a case in point, a project engineer expressed that having a shared vision in a collaborative project leads to a strong relationship among the involved partners and facilitates IOC. A developer argued that common goals and a shared vision in IOPs assists the collaborative parties to create a clear picture of what will actually happen in a project.

The root of successful collaboration in a project, according to the respondents, is the fact that people involved in IOPs are working together and internally negotiating and jointly searching for the next steps to efficiently complete a project. A senior manager asserted that teamwork and jointly performing a project result in a quality increase, and a reduction in cost and duration. The respondents confirmed that collaborative processes, such as making a joint agenda with the other partners, and engaging in regular collaborative meetings, result in intensive teamwork and sharing of various parties’ data during

collaborative work, which contributes to joint problem-solving, creating innovative solutions, and improving IOCs.

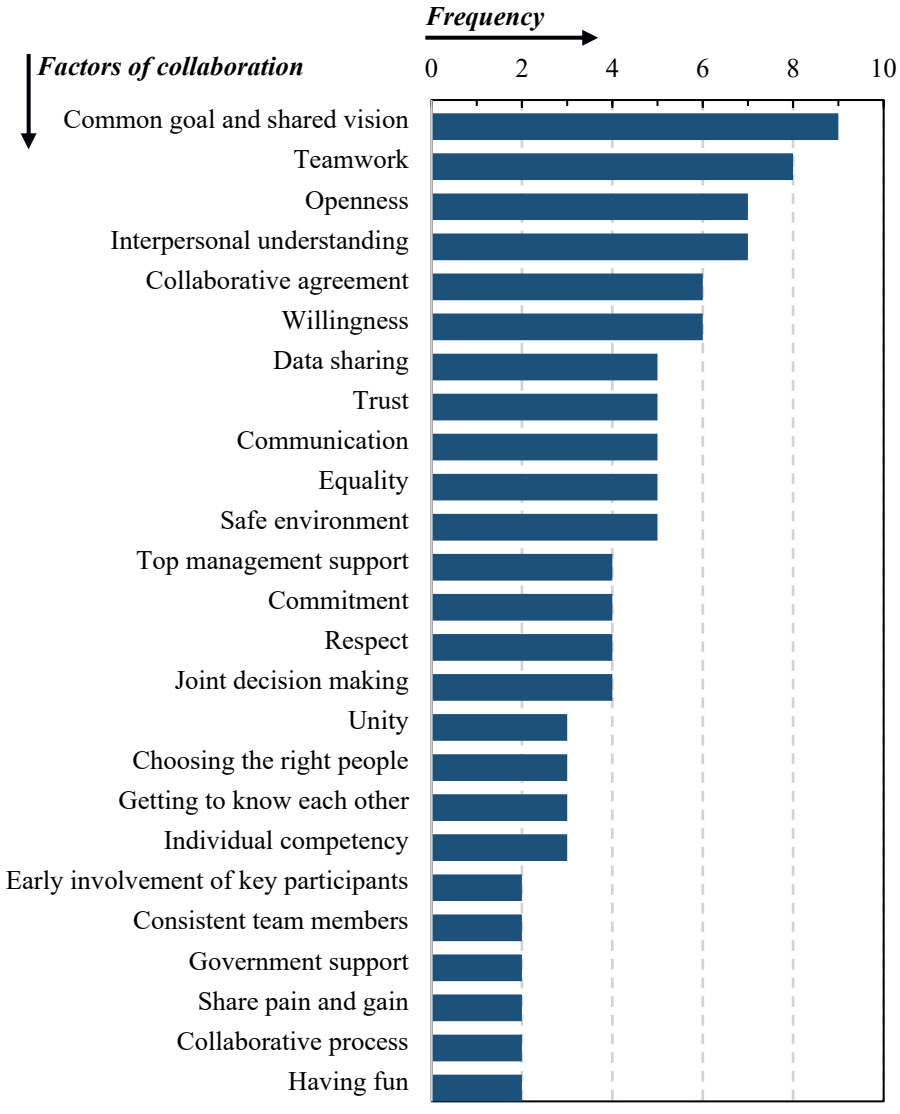

Figure 2.1. Factors facilitating collaboration in IOPs.

As reported in the interviews, openness was considered by practitioners to be one of the main factors of IOC contributing to efficient teamwork and collaboration. A director expressed that openness in IOC leads to a common ground, common understanding, and a common definition of the issues. A strategy director mentioned that being open and transparent during an IOC, and particularly regarding collaborative issues, can contribute to timely solutions for potential issues. As quoted by an adviser, "*if there is openness and trust among collaborative parties, you can prevent potential conflicts and discuss your issues and requirements openly with collaborators which causes a close collaboration of parties*".

A project executive added that "*having open and transparent communication with other partners is required to keep track of the goals of the project and to deliver more than we planned in collaborative projects*". Respondents claimed that open and transparent communication results in outcomes that go beyond expectations and add value to the project. To realize such achievements, a project manager stated that sharing data through communication is required to move toward the same goals in a collaborative project. Sharing data through communication indicates openness among collaborators. Respondents argued that data sharing plays a significant role in accommodating transparent communication, which helps fulfil milestones in collaborative projects.

According to the interviews, interpersonal understanding was another important factor of collaboration that requires sharing what each actor knows. In this regard, a respondent mentioned that meetings with partners and listening to other points of view led to mutual understanding. An adviser argued that understanding each other leads to communicating with the same language with other partners. The respondents believed that data sharing is necessary to understand each other when collaborating with other infrastructure owners with different perspectives: "*we have to share our data and experiences in*

collaboration with other infrastructure organizations to understand each other's world and to get a step ahead".

In addition, the interviews indicated that data sharing is a substantial factor in collaborating with other organizations and creating innovative works. A project manager supported this finding by claiming that "*in this infrastructure and building sector if you do not exchange data then creativity and innovation will always die*". Establishing an efficient platform and a solution for the exchange of data is essential for a fruitful collaboration. Confirming this opinion, another project manager mentioned that "*we have to tell them [the other parties from different organizations] what we know, and they have to tell us what they know. Then we can bring the data together and based on the shared data, we can come up with an idea to do a project*".

The respondents argued that data sharing is required for joint collaboration and building a common agenda: "*we together with the other partners made up the agenda by sharing our data and experiences*". An adviser considered sharing data as a means to achieve collaborative goals: "*sharing data provides better insight into the collaborative project and helps to make fewer mistakes in implementing a project*". The respondents stated that data sharing, especially during the development of the project scope, leads to integrated work with other partners. Data sharing is, thus, the main element of decision-making in collaborative projects. As quoted by a director, "*we work on interconnected infrastructure projects, which require all relevant data from other infrastructure owners to be able to make efficient and prompt decisions during an IOP*". According to the interviews, joint decision-making was one of the identified factors of IOC which required sharing data from various collaborative parties. The respondents accordingly underlined the impact of open data sharing: "*if you collaborate towards a common goal, you want to share your data for free and in this case, nobody was allowed to keep data behind. If you are interested, you*

should open up your network". Respondent thought that openness and data sharing are critical factors contributing to collaboration in infrastructure projects.

2.4.2. The status of data sharing in IOPs and whether collaboration facilitates data sharing in IOPs

In this section, the interpretation of data by the respondents is explored as well as the status of data sharing and whether collaboration influences data sharing in IOPs. The respondents interpreted data as "*an asset*", "*an input that you can interpret*", "*raw figures*", "*the basic information*", and "*a means to achieve the goal*". Moreover, data were defined as "*a package of knowledge*" by a project manager, who also stated that "*data in itself is nothing. It is how you interpret it and what you do with it*". She believed that data sharing is needed to progress the project. An adviser supported this argument by adding that data can be important, especially for operation and maintenance, wherein using previous data can facilitate maintenance or rebuilding. Data sharing is considered to be required to start the project and make a design of infrastructure projects.

All respondents in preliminary interviews indicated that there is a lack of data within infrastructure organizations although data are required to make a decision in different steps of a project or convey a sound analysis towards the next step. According to the respondents, it is difficult to obtain data, since not all the data are accessible and/or they are not necessarily digitalized. Data related to old projects are especially lacking, said an adviser: "*the old drawing of the rainwater system was missing, we had to do a lot of research to recover data. We lost a lot of data at some stage. We have to reinvent a lot of things*". A project leader also highlighted that because of missing data and improper storage, a lot of rework happens during projects, which prolongs the IOP.

Regarding the improper storage of data, a senior adviser stated that "*some of the data were stored but you don't know where and with which names and formats the data were stored*". In the case of providing database access to

external parties, it is also problematic to clarify what they need from it. Although internal platforms exist to store and share data within an infrastructure organization, it also possesses its own shortcomings. Data platform systems are typically not up-to-date, and the data connection is very slow. Therefore, people rarely use it very strictly and tend to store their data on their hard disc, resulting in data loss for future projects. In addition, data must be stored in a special format on a platform. Otherwise, the data platform would become less beneficial in practice due to the different formats of various types of data. This issue is more pronounced in collaborating with other infrastructure owners since each organization has its own formats and standards to store data.

There is also a risk of data loss between different phases of the lifecycle. Respondents reported data loss after completing a project by the partner. In addition, each department in an organization owns its data, and after finishing the project they start another new project without storing them. Therefore, data are lost. A project leader stated that "*everyone is saying that it is not my job to store the data. So, for every project, we have to do that again and again*". Storing and assembling data are not attractive either. An adviser assumes data and storage of data as "*the black sheep of the family*"; it is not an appealing work. He explained that reorganization (for instance, job creation or elimination) causes data loss. According to the respondents, data loss can also be caused by changes in the contract and lifecycle phase, system and software updates, and policy revisions.

As mentioned, the organization's policy is sometimes at the root of being unwilling to share data. In one of the interviewed project manager's opinions, and according to his organization's policy, they were not allowed to share data. However, data are necessary to collaborate with other organizations. He declared, "*we had to share what we know and bring our data to the table and take a look at them to come up with an idea and an efficient solution*". Therefore, they had to make use of each other's data illegally. Based on the policy of an

organization, data can be confidential or sensitive, meaning they cannot be shared with other parties. In addition, some infrastructure organizations consider data as an organization's power, and they are unwilling to share it. One respondent commented that "*you are talking about power; it is their data. They are saying that they are going to share their data, but they never do that. They are very protective of their data*".

Besides the lack of data, the quality of the existing data is not satisfactory either. An adviser mentioned that "*the data set was not compatible or not being checked. If the basic data at the beginning of the project is not reliable, what are you going to do? You have to measure everything and do the investigation again*". This inconsistency in data is as problematic as the lack of data. A senior manager mentioned that "*we are still lagging behind in data quality, so we can't share the data*". A developer also argued, "*if there is no standardization then you don't have a data quality definition, because you are always talking about something else*".

The respondents named data quality as a critical bottleneck in infrastructure organizations. It is mandated to have metadata to describe and clarify the data, as it can increase the accuracy of data. The metadata differs for every infrastructure organization depending on the type of data they use. In the view of a senior manager, there is an issue when it comes to collaborating with other organizations "*if the other organizations have adequate metadata with accuracy to combine it with our metadata which differs from theirs, it caused the problem because they use different standards*".

Despite challenges in data sharing, such as a lack of data and low quality of data, the factors for facilitating data sharing in IOPs were identified based on the respondent's point of view which are presented in Figure 2.2. Figure 2.2 shows that standardization of data, openness, digitalization, and making an agreement

are the factors which were most frequently mentioned by the respondents to facilitate data sharing.

The interviews revealed that one of the challenges of data sharing between various infrastructure owners is to make the data usable and understandable for all parties. Each organization, and even each department in an organization, had a different format, standards, and semantics for data. Therefore, it was not crystal clear how they can exchange the data and how they may realize that it is an identical issue they are discussing which necessitates the standardization of data to share it among various organizations. As explained by an adviser, there was a manual for data delivery in her organization, which explained the specific format and quality of data that should be delivered. However, various data formats in IOPs are a challenge, according to the respondents. As a senior manager suggested, by using linked data and shared platforms, various partners can transfer their data according to a certain standard model. In addition, using linked data and categorizing the data led to higher accuracy of the data and would also be beneficial for a digital twin. He mentioned, "*if we want to extend or maintain the infrastructure with other organizations, we can put the specific data (based on the categories) in the model, and with linked data, we can choose what data we need*". He declared that his organization did the first experiment of linked data with their database. However, they discovered low quality and inconsistencies in their data, which hindered the process of implementing them. This issue necessitates optimization of internal data in an infrastructure organization.

As reported by respondents, openness is one of the main factors contributing to data sharing. As quoted by a senior manager, to share data efficiently, openness is a key: "*if you need to share data efficiently in IOPs, then nobody should close their doors*". Thus, being open and providing open space facilitates data sharing and leads to creating novel solutions through the various perspectives and ideas of involved participants. In this regard, a project manager

stated, "*if you collaborate with other participants and have a common goal, you are interested to open up your network and share your data for free*". She also added that tending to work in a collaborative environment and hoping to find new solutions together lead to data sharing and being open in IOPs. Actually, an adviser mentioned that the willingness to work with different people in a certain environment is one of the factors facilitating data sharing. She believed that the willingness to collaborate often stimulates participants to share data among themselves, mainly because they see it as an opportunity to achieve their own goals.

According to all respondents, another data-related challenge is that there is no written record of them. Most data are in the heads of people. To gather the required data for the project, they used email, or they met their colleagues and verbally asked them what they needed. Such an unstructured approach results in data loss and data entrapment within a specific group of a single department in an organization: "*in infrastructure organizations, it is still the case that a lot of data are in between the ears of individual people or in someone's cupboard*", which hinders sharing data not only within the infrastructure organization, but also between various infrastructure owners for projects.

Due to the lack of digital files of old data, data gathering is also a problem within infrastructure organizations. A project manager addressed this issue by referring to the need for historical data to develop an infrastructure: "*we don't know what happened 50 years ago and what kind of materials and techniques were there. What we can do is to make a good guess because there are no digital files of data yet*". A developer added that to access data and share it after a long time, data digitalization is needed: "*at some point, your paper archives will be destroyed and the digital ones can be kept longer, but to what extent do you digitalize your data?"* As reported by respondents, digitalization facilitates data sharing in IOPs and enables managers to control project processes.

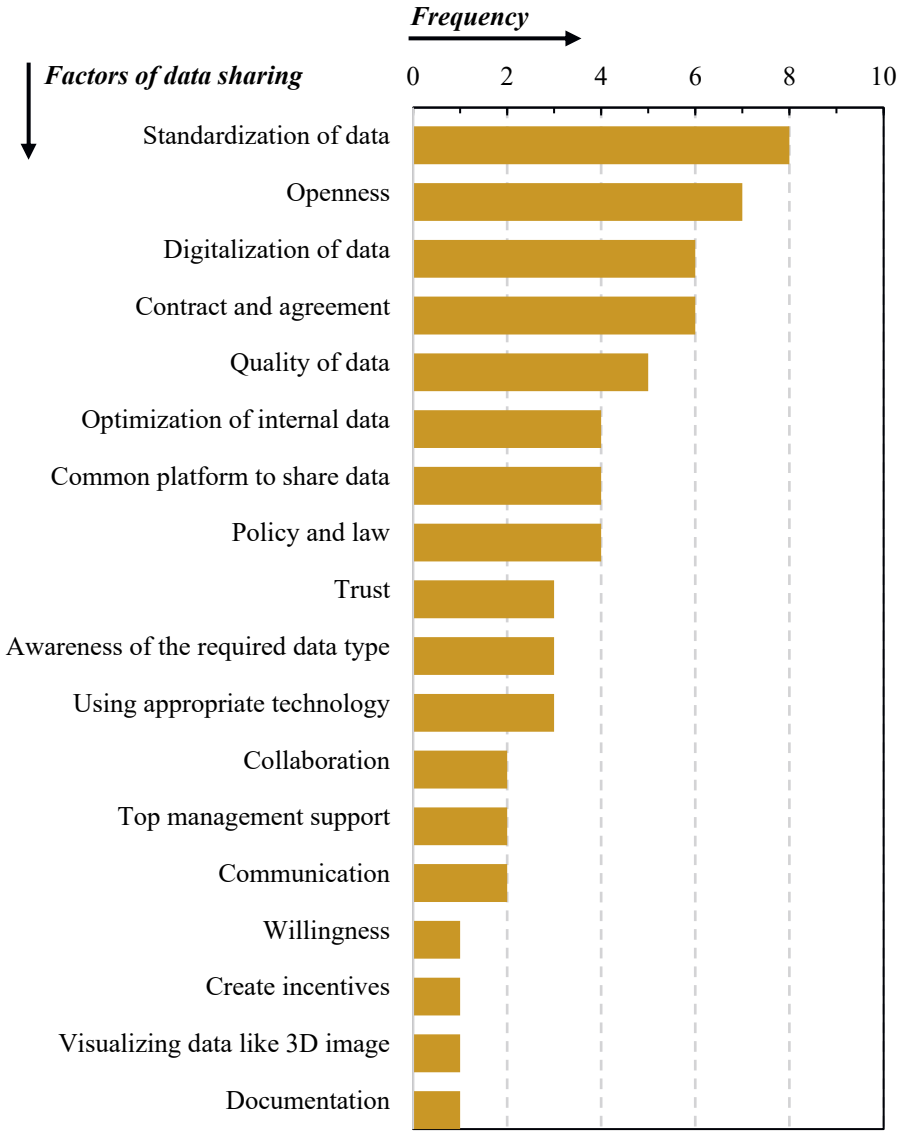

Figure 2.2. Factors facilitating data sharing mentioned by the respondents.

The respondents stated that organizations need to make agreements on data sharing between them in the case of collaborative projects to ensure that data are accessible, inter-operable, and (if needed) reusable. The quality of data, as a critical factor for data sharing, as well as the responsibilities of participants for

data management (*e.g.,* collecting, storing, and sharing), should be discussed and included in such agreements. Moreover, one of the challenges of data sharing in IOPs is related to data classification and confidentiality. Contractual agreements can play a critical role in determining how data should be shared and what data should be expected from other partners during and after a collaborative project. As a developer noted, certain legal or contractual conditions are required to filter the shared data. A project manager also indicated that they just shared the data relevant to the context and skipped relaying a mass of data. However, the practitioners believed that it is difficult to recognize the relevance of data and the interesting portion that could be used in ongoing projects.

Moreover, since each actor in an IOP may have unique data that might not be available in the other infrastructure organizations, despite being useful and valuable, each organization needs to explore and look for those data in the other organization through communication in a collaborative work environment. This line of communication demands gathering different participants in a collaborative environment.

An adviser also pointed to a critical point about synergies, stated that collaboration with each other leads to a joint result that is better than the individual outcome: "*when I work with you, you know something, and I know something, and we can make the best result out of it*". Therefore, collaboration is required to utilize data and experience of other infrastructure owners. A senior manager supported this statement by saying "*infrastructure managers will search for a way to share certain data between particular parties if they work collectively on the project*".

With regard to hierarchy and the importance of individual members, a project manager argued that in a collaborative environment every participant is equal and there is no hierarchy, stating that "*we are a group and there is no boss, no company. There is a team and all the data at the table is for everybody. So, there*

is no single ownership of data there". A senior adviser highlighted this argument by adding collaboration as a factor that facilitates data sharing. He stated that due to the fear of the participants for their positions, the participants were reluctant to share their data at the beginning of the project. Therefore, because of the competitive advantages and the fear of small organizations losing their positions in the market, there are insufficient incentives for data sharing. However, by establishing a collaboration between different organizations and providing a collaborative environment with mutual respect, they can overcome their fear.

On the importance of appreciating all individuals and partnering parties, a project leader stated that to broaden the scope of the infrastructure project and gain innovative ideas, various perspectives and data are required: "*we don't have enough data to broaden the scope of the project, thus we invited the participants from different organizations to collaborate*". Therefore, data sharing among different infrastructure owners was considered indispensable to achieve innovative solutions and to realize opportunities in an infrastructure project, which is only feasible by bringing the infrastructure owners together to collaborate. Similarly, a project manager argued that getting to know each other's world is crucial before data sharing with other infrastructure owners: "*we need to get to know each other in order to see what kind of plans fit both interests. If you don't know that, data sharing is not going to work*". Getting to know each other's world and interests entails bringing different participants together to facilitate collaboration. In addition, getting to know each other was one of the factors of collaboration mentioned in Figure 2.1 that facilitates collaboration between various organizations, which finally contributes to data sharing in IOPs.

2.5. Discussion

The complex nature of infrastructure projects, the interrelatedness of their designs, and the involvement of various disciplines and multiple stakeholders in these projects (Ping, Keung, & Ramanathan, 2011) make collaboration and

pooling of resources (particularly the data from various infrastructure owners) between various infrastructure owners indispensable. Infrastructure practitioners have recognized that limited space and resources currently hamper infrastructure development in the Netherlands; hence, they increasingly understand the necessity of collaborating with various infrastructure owners. However, in practice, practitioners were seldom engaging in IOC. Consequently, this research encountered only very basic forms of IOC; infrastructure owners primarily work independently (in parallel) or, at best, within the context of a larger project. Accordingly, infrastructure practitioners focus on organizational goals rather than project goals, which in the long run can result in poor project outcomes.

The results from this research also indicated that silos exist not only between infrastructure owners, but also within the organizations themselves. Infrastructure organizations are quite hierarchical and bureaucratic, which hampers 'horizontal collaboration' and data flows between different departments. The silos hinder collaboration by making it impossible for practitioners to exchange ideas about a problem and to develop and "speak the same language" (Engeström, Engeström, & Kärkkäinen, 1995). One of the challenges in inter-organizational infrastructure projects is the development of truly horizontal collaborative structures.

The results presented in Figure 2.1 suggested that IOC relies, to a large extent, on factors such as a common goal and shared vision, openness, trust, willingness, and communication within a collaboration. Among various factors that the practitioners mentioned, data sharing played a significant role. Data sharing acts as a mediating factor, which in turn enhances key aspects of collaboration such as common goals, interpersonal understanding, collaborative processes, joint decision-making, and openness. Respondents identified data sharing as a major factor affecting collaboration. However, data sharing was restricted because of organizational policies: employees of infrastructure owners were not allowed to share data or had to consider unauthorized data sharing as a possible solution.

Practitioners advocated updated organizational data sharing policies to facilitate collaboration in IOPs. Hard aspects which structure collaboration and data sharing, such as laws, policies, and contracts or agreements, are essential for IOCs. These expressions conformed to the literature, which emphasizes the importance of a collaboration agreement (de Jong & Smit, 2012; Suprapto, 2016). It was also argued that contracts and agreements can facilitate data sharing in inter-organizational collaborative projects and improve transparency and stimulate data security.

In the case of working collectively in a collaborative environment, data sharing was considered indispensable. However, in infrastructure projects, the availability and accessibility of data are still an issue. The present research results revealed that data are often shared by practitioners via email, personal chats, or via paper archives, leading to data loss for the next phases of a project or future projects. According to the respondents, a lack of data is a challenge not only in IOCs, but also in intra-organizational collaborations. To realize data sharing in IOCs, an awareness from infrastructure owners of the power of data, especially in the early stages of the project, and the importance of organizing and structuring the data, are needed.

Respondents concluded that the collaboration of infrastructure managers from various organizations poses additional challenges for data sharing, as various data formats are used by different infrastructure organizations. In this regard, respondents suggested restructuring data to conform to a predefined standard (established by collaborators) to ensure the usability of data being shared in a collaborative project. This would eventually result in a better understanding of each other and reaching common goals that are essential to collaborate with other organizations.

The development of a resilient infrastructure could logically be supported by data sharing between infrastructure owners. Collaboration between

infrastructure owners is essential to acquire data that supports synergies in infrastructure projects and development of innovative solutions. The results presented in Section 2.4.2 suggested that collaboration can facilitate data sharing in IOPs. Collaboration relies on win–win situations (Suprapto *et al*., 2015) and provides an opportunity for organizations to share their data and experience to achieve common goals without having major concerns about losing their position and power due to the ownership of particular data. Therefore, collaboration offers an opportunity to gain added value from data sharing and facilitates a data flow among the involved parties.

The present study revealed the common factors of collaboration and data sharing, including openness, trust, policy and law, agreement, top management support, willingness, and communication with other partners in IOPs. These factors are a combination of soft factors (related to the relational aspects in IOP) and hard factors (related to the structural aspects in IOP), which are presumably needed for collaboration as well as data sharing. For instance, communication with other partners facilitates data sharing. The provision of a collaborative work environment is necessary to have a strong line of communication with other partners (Stryker, 2004), while such a collaborative work environment facilitates data sharing between different participants. Data sharing via communication is required to establish such a collaborative work environment and achieve common goals in a collaborative project.

Similarly, trust contributes to accommodating parties who are willing to share data (Ho, Kuo, & Lin, 2012). The importance of trust for data sharing and collaboration has been extensively emphasized in the literature (Kuo, 2013; McCauley & Kuhnert, 1992; Renzl, 2008). Trust among participants in collaboration reduces the fear of losing participants' unique values, which subsequently, can increase the willingness for data sharing (Hinds & Pfeffer, 2002; Renzl, 2008).

It was also perceived that different participants could jointly work together by applying collaborative policies and laws, which can also facilitate data sharing in collaborative projects. Based on the common factors that were identified in the present work, collaboration and data sharing appear to be interdependent. In other words, data cannot be shared effectively without some form of collaboration and vice versa. Hence, it is postulated that a bilateral relationship exists between collaboration and data sharing. Collaboration and data sharing influence each other; thus, an improvement of IOC between infrastructure owners would facilitate data sharing in IOPs and vice versa.

2.6. Conclusions

The objective of this research was to investigate the status of collaboration and data sharing and their relationship in inter-organizational infrastructure projects. To this end, semi-structured interviews were held with practitioners at the organizational level and at the project level in the infrastructure sectors in the Netherlands.

Based on what was discussed, collaborating with other infrastructure owners in other words IOC is essential to deal with challenges such as scarcity of land, silo effects, and resilience towards future changes. IOC enables the consideration of different alternative scenarios and future needs to design interconnected infrastructure projects, making the next-generation infrastructures more resilient and adaptable to future changes. However, how infrastructure owners tackle infrastructure projects does not qualify as real collaboration. It is required to create a collaborative environment and establish a collaborative baseline to improve and facilitate IOCs. Such a collaborative environment would provide an opportunity for multidisciplinary parties from various infrastructure organizations to collaborate in an integrated manner and share their resources, such as skills and data, to achieve their common goals and deliver the best possible solutions. Working in a collaborative environment, different parties

would benefit from sharing risks and responsibilities, and they could acquire complementary resources including data. Additionally, a collaborative environment creates equality, eliminates hierarchies between parties, and facilitates data sharing.

In addition, IOPs in the Netherlands face difficulties in data sharing. One of the reasons for this is the current state of data storage and sharing. Infrastructure practitioners reported a reluctance of infrastructure owners to share data because of the confidentiality and sensitivity of the data, privacy concerns, restricted policy of organizations regarding data sharing, low quality of data, different formats and standards of data, a lack of digital files of data, and because data are considered part of the power of an organization.

Practitioners also identified problems with data within their organizations as well in IOPs. Among the problems, heterogeneity of data formats and standards was identified, which influences data sharing and causes improper interpretation of data and misunderstandings among collaborators, reducing the value of IOCs. The practitioners believed that improvement, optimization, and standardization of organizations' data are required to enhance the quality of data to enable data sharing in collaborative projects. Data standardization and knowing the formats and standards of collaborating partners could lead to coming up with a shared language and understanding of mutual data, which would necessitate collaborating with other infrastructure owners and knowing each other.

Data sharing between infrastructure owners was considered important for IOPs. Sharing data across infrastructure organizations is required to realize innovative solutions in IOPs, which needs trust and a collaborative environment among the organizations. However, data sharing still has fundamental problems in IOPs. It is concluded through the practitioners that data sharing and management are still in its infancy, and that exchanging data streams in IOPs is an ambitious target that is yet to be achieved. Thus, it is required to take one step

back and first focus on establishing better collaborations between infrastructure owners in IOPs, which, in turn, will assist with the sharing of mutual data.

The factors influencing collaboration and data sharing in IOPs were explored through the interviews, including soft factors such as openness, and trust, and hard factors such as having a contract. Some factors, such as trust, contribute to both data sharing and collaboration. Both collaboration and data sharing have common underlying factors, highlighting the possible relationship between them. Collaboration seems to require data sharing, but data sharing also seems to require effective collaboration between different organizations. Thus, collaboration and data sharing are intertwined. On the one hand, data sharing is essential to collaborate with infrastructure owners. On the other hand, a collaborative environment in IOPs is required to facilitate data sharing.

Further research is required to test the relationships between collaboration and data sharing. The scientific contribution of this research lies in the identification of important factors of collaboration and data sharing in IOPs. Additionally, with interrelated collaboration and data sharing, considering and enhancing the factors of both collaboration and data sharing in parallel are essential to successfully conduct IOPs. Nevertheless, the role of collaboration to facilitate data sharing has rarely been addressed in IOPs and needs extra attention.

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3

The Key Challenges of Inter-organizational Collaboration in Interconnected Infrastructure Projects[2]

Highly interconnected infrastructures and their interdependency make the execution of projects complex, urging the use of multidisciplinary knowledge, expertise, and skills to construct and manage the next-generation of infrastructures. To fulfil the societal and environmental requirements and to deal with future demands and complexities, a collaboration between different infrastructure organizations, *i.e.,* inter-organizational collaboration (IOC), is indispensable. However, bringing different infrastructure partners from various organizations with different backgrounds, skills, cultures, and perspectives together to collaborate has numerous challenges. The present work aims at identifying these possible challenges of IOC based on practitioners' perspectives. The practitioner's perspectives are explored through case studies of inter-organizational infrastructure projects in The Netherlands. The identified challenges of IOC are categorized into two dimensions based on the responses of the respondents: a structural dimension and a relational dimension. Recognition of possible challenges of IOC assists infrastructure owners in foreseeing and overcoming them adequately.

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3.1. Introduction

Infrastructures are the cornerstone of the economic growth and future development of countries. Nowadays, these infrastructures have more interfaces with each other and are highly interdependent. These strong interdependencies influence their performance and generally cause complications, motivating organizations to coordinate their efforts with one another (Armstrong & Jackson-Smith, 2017). Moreover, infrastructures are becoming more complex to address upcoming global challenges such as climate change, enhanced sustainability, and pandemics, which necessitates infrastructure owners with various expertise, experience and knowledge to collaborate. However, previous studies have revealed that the majority of mega-projects in the infrastructure sector do not finish within budget and/or schedule (Flyvbjerg, 2007; Lichtig, 2010; Montrimas, Bruneckienė, & Gaidelys, 2021). To address these issues, integrated functionality and joint activities are essential to develop new infrastructures by combining the multidisciplinary knowledge, expertise and resources of various infrastructure owners. Therefore, effective management of interconnecting infrastructures and close collaboration between the asset managers particularly in the early stages of the projects (Aghimien, Aigbavboa, Oke, & Setati, 2018) are vital to optimize the efficiency and effectiveness of infrastructure development.

Collaboration between various infrastructure owners (*i.e.,* inter-organizational collaboration (IOC)) with highly interdependent parties can bring opportunities to create added value in infrastructure projects. Collaboration is the working of various parties together interdependently to gain greater value and purpose than they can achieve individually (Lu, Elmaraghy, Schuh, & Wilhelm, 2007; van den Broek & van Veenstra, 2015). Gray (1990) defines collaboration as "*a process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible*". IOC aims at leveraging the diversity

of parties involved in a collaborative project in terms of knowledge, skills, and resources (Hardy, Lawrence, & Grant, 2005) and exploring innovative solutions for complex problems (Greer, 2017).

Despite the potential of collaboration to generate impressive outcomes, not all collaborations are successful and may even fail to create innovative solutions and collective functions in a project (Hardy *et al*., 2005). According to Lu *et al*. (2007), inefficient collaboration leads to project failure, unwanted reworks and delays. Collaborative designs of interconnected infrastructures due to the increased number of interfaces are inherently more complex than individual designs (Lu & Cai, 2001). Moreover, multiple collaborative actors in infrastructure projects may have various perspectives on collaborative work processes. Accordingly, conflicts and complexities during the design process can make collaboration among multiple participants challenging (van Marrewijk & Smits, 2016).

Besides, collaborative relationships include a broad range of issues such as assigning roles to different parties and the type of problems that should be addressed (Phillips *et al*., 2000). According to Hardy *et al*. (2005), having an effective IOC is challenging mainly due to fulfilling the interests of various involved organizations. Additionally, the complexity of interpersonal relationships in IOC affects the success of collaboration and should be understood (Majchrzak, Jarvenpaa, & Bagherzadeh, 2015). Hardy *et al*. (2005) also state that relationships among the involved parties and communication among them can lead to effective collaboration. Identifying the related issues in IOC as well as the essential factors of successful collaborations are indispensable for the realization of effective IOCs.

Emuze and Smallwood (2014) discussed the level of collaborative work between different parties in South African construction and identified the main problem through a survey among contractors in the supply chain. They reported

that major problems in collaboration are rooted in a lack of trust, the fragmented nature of the design process, and not involving the key parties at the early stage of the process. Emuze and Smallwood (2014) classified the identified problems into three categories: relationship, process, and customer focus; however, the identified problems are mainly related to the construction process rather than a collaboration of various parties. Huxham, Vangen, Huxham, and Eden (2000) described the structural complexity and the challenges related to collaborative governance. They addressed several challenges in collaboration based on two dimensions: structural and diversity. The structural dimension includes different ways of interactions and the various extent of involvement of key members in a collaboration, ambiguity in the roles and tasks of the involved parties, and the dynamic environment during a collaboration. Dimension of diversity includes differences in resources and aims, cultural differences, and power differences. It should be noted that the work of Huxham *et al*. (2000) focused primarily on structural issues and governance in collaboration, particularly in community-based organizations, hence the issues related to the other aspects of the collaboration, especially in infrastructure projects, are not addressed.

According to Lu *et al*. (2007), collaboration and its underlying issues are neglected and misunderstood in practice, however, collaboration is an integral part of a project. Akintoye and Main (2007) studied the collaborative relationship in construction and described the perceptions of contractors in collaborative work and the factors of success and failure for collaborative relationships in construction. They also stated that "*less attention to the issues regarding the collaboration*" is a failure factor for collaborative work.

The goal of the present work is to address the possible challenges and issues of IOC based on infrastructure practitioners' perspectives. To this end, possible challenges and issues of IOC are identified based on case studies and interviews conducted with the key participants in inter-organizational infrastructure projects in The Netherlands. Awareness of the possible challenges and issues of IOC

prepares the involved infrastructure owners to foresee the possible barriers of collaboration and seek feasible solutions to overcome them facilitating an IOC.

3.2. Research methodology

Over the past years, case studies have been done to learn about IOC in interconnected infrastructure projects and to facilitate this type of collaboration. Case studies can be used to perceive the circumstances of a case and its complexity (Hollweck, 2015). Through the case studies, the possible challenges and issues regarding IOCs in interconnected infrastructure projects are explored and described in the current research. To this end, three case studies were performed to obtain the practitioner's viewpoints on IOC. These cases are the sample of interconnected infrastructure projects performed by different infrastructure organizations (*i.e.,* road, rail, aviation, water and energy) in the Netherlands. Two of these cases are completed projects and one of them is a running project. The aim of these cases is a replacement and/or development of the infrastructures in the Netherlands which require the collaboration of different infrastructure owners due to the interconnectedness inherent to infrastructures. The data was collected through semi-structured interviews with key participants in the projects. 25 practitioners were interviewed in total. The interviews were recorded and transcribed to extract the relevant information using qualitative data analysis. Table 3.1 shows the overview of the respondents based on their functions. The names of the interviewees and the projects are anonymous due to confidentiality purposes.

Table 3.1. The overview of the respondents based on their function.

Function	Number of respondents
Project manager	6
Project director	5
Advisor	3
Coordinator	2
Technical manager	2
Integrator manager	2
Contract manager	2
Developer	2
Stakeholder manager	1

3.3. Results

The issues and challenges of IOC in interconnected infrastructure construction projects that practitioners have faced during their collaborative works are identified in the present work. The majority of the respondents consider the policies and rules of the organizations involved in an IOC as the main issue. The variety of rules and guidelines of organizations affects the decision-making processes and procedures of collaborative work. One of the project leaders supports this argument that some parties are more formal with a high level of bureaucracy than others are, disturbing the harmony of collaboration. According to the respondents, procrastination also augments in different phases of collaboration due to the political considerations between different organizations and the bureaucratic procedures across hierarchical levels to get approval.

This challenge can be even more pronounced in collaboration with governmental organizations with restricted rules and policies. In this line of reasoning, one of the coordinators mentions, "*we have our own rules, and everything is clear for us. However, in this project, we have to collaborate with other infrastructure organizations, and that means we cannot always apply our*

own rules, as we are used to in our own projects, and this is a bit difficult". Additionally, the rules of the parent organizations are strict, one should not deviate from them, and this causes a conflict among the parties during the collaboration.

The other challenge is related to the discrepancy of working attitudes in different infrastructure organizations. Since each organization has established their own procedures and approaches to execute projects, contradictions may occur among parties in an IOC. One of the advisors remarked, "*During the collaborative project, some of the organizations were interested in detailed content and specific data, but they are not the core focus of the other organizations in order to perform the specified topic in the project*". A project director states that discordance between organizations' working attitudes causes problems in managing a collaborative project and hampers collaborative work. Similarly, one of the project managers states, *"we deal with a situation that one of the parties says I cannot give you a green light, because you didn't follow our procedures".* Therefore, it is advised to discuss these differences beforehand although it might be time-consuming. Another project manager adds that redesigning the common collaborative working attitude could enhance IOC.

The existence of different interests among parties is another challenge that the respondents have faced during IOCs. According to the respondents, each party has its own interests in an IOC and attempts to realize them and often neglects the other parties' interests, leading to tension among parties. A contract manager sees the organizations as two neighbors who think about their own gardens and protect them without considering the common walls in between. Conflict of interests among parties is more notable in the interfaces that require commonality and strong collaborative relationships.

Four of the respondents also believe that being unclear about the real interests of their own organizations and not discussing them clearly with the team is a

potential issue in a collaboration. A project leader mentions that if parties are unclear about their real interests, it could impede solving issues timely and lead to a deteriorating collaboration. A contract manager states that the interests of each party should be explicitly discussed to build a common picture of the project. In this line, a project manager says, "*we encountered lots of disagreements from one of the parties who were not clear about their interests and demands at the beginning of a collaborative project*". The person believes that the involvement of different infrastructure owners in an inter-organizational project necessitates understanding their interests and demands to establish integrated collaboration.

Attaining the interests of parent organizations that may conflict with one another also puts pressure on the project team. A respondent considers this as a big challenge that they should deal with during IOC. A project director mentions, "*All cases of difficulties in IOC come back to the point that people are representing their organizations and cannot act as a person*". Therefore, they have to pursue the organizational vision in the project and fulfil the demands of their own organizations rather than project demands. According to one of the project integrators, there is an opportunity for synergistic collaboration by combining the goals and resources of different infrastructure owners; however, it requires convincing the parent organizations. Therefore, the pressure that is put on the project team by the parent organizations to realize their own goals is a substantial challenge.

One of the main challenges mentioned by practitioners is changing the team members during a project, particularly during a specific phase of a project. In this regard, a project leader expresses that "*at some point of collaborative work the involved members from different parties should not change, otherwise you have to explain the discussion points again and start all over again. In this case, there will be no progression in the project line of thought"*, which may lead to a delay in the project.

A contract manager argues that changing team members even between different phases of a project is a challenge because the new team member does not have a common history of the collaborative project, which leads to discontinuity in IOC. This person also believes that both counterparts should not change at the same time. Excessive changes in the team disturb the processes because they have been discussed and agreed upon with the predecessors and may not be embraced by new members. A project leader also adds, "*we have a challenge in our collaboration by replacing a manager at a specific stage of a project because she had different perspectives and different ideas of where the project needs to go*". Hence, more time and effort are required to understand each other's perspectives and create a common ground among a collaborative team once new key members join a collaborative work. Therefore, successive changes in a collaborative team in a short time is an effortful challenge during collaboration, since IOC consists of multi-actors with various backgrounds, cultures, experiences, and perspectives.

Another challenge in IOC roots in the disparity of professional languages and terminology used in various organizations, leading to misunderstanding in a collaborative project. A project manager believes that collaborating with other infrastructure organizations is challenging because of misinterpretation during the collaboration, as "*they listen with different ears*". According to a project director, different interpretations of the parties can augment conflicts that arise due to misunderstandings in a project. A project director supports this argument by saying that" *if you come from different organizations or different perspectives in all kinds of ways then certainly at the beginning of a project even if you use the same words, you don't mean the same thing*". This challenge makes it difficult to create a common ground among various infrastructure parties in collaboration. Different understandings of similar subjects and notions across organizations lengthen the decision-making processes with many discussions to achieve an agreement.

According to the respondents, disunity among the collaborative team can trigger conflicts between organizations and lead to inefficient IOC. A developer expresses that some organizations tend to use the term "*my domain and your domain*" in a collaboration, which can weaken the collaborative relationship. A technical manager also states that the first step towards having an effective collaboration and achieving common goals is being one team for one project. One of the project managers supports this argument and mentioned that "*if one party has a problem, that means all parties have a problem and together should we solve it because we are on the same boat*".

Another challenge mentioned by respondents is the dominant position of some organizations, causing conflicts in IOC. The organizations owning a large territory of the project or being governmental organizations feel more powerful during a collaboration. This affects the decision-making processes and creates a feeling that the parties are unequal. According to the respondents, the dominant organization considers the project as their own project rather than a collaborative project and neglects the impacts of decisions on the other infrastructure owner, which is often a frustration for collaboration at the project level. A senior advisor mentions, "*By losing ownership and being part of the team, you can collaborate integrated otherwise you always fight during the collaborative work*".

The other issue mentioned by practitioners is the monopolist position of some organizations. Such organizations are oriented to their own working processes and are unwilling to change. However, the ability to think differently and being ready and willing to adapt to changes is key to collaborating successfully with other infrastructure owners with different processes and perspectives. One of the advisors states that the conservative culture of some organizations hinders collaborative relationships, "*one of the involved organizations has a conservative culture and followed the traditional approaches while the other one was looking for new possibilities and new ways to implement the project*". This kind of cultural difference among parties not only hinders collaboration but also

impairs innovation in collaborative work. Therefore, cultural differences among parties involved in an IOC are one of the challenges that infrastructure practitioners face. One of the coordinators believes that cultural difference among the organizations is a challenge, which causes misunderstanding during collaboration. Additionally, appreciating cultural differences between organizations can promote an understanding of one's organizational behavior and overcome potential conflicts among organizations.

According to the respondents, past experience of involvement in an IOC has an impact on a collaborative relationship. Two of the managers consider the previous unsuccessful experience as one of the challenges that they faced during IOC. According to a stakeholder manager, some of the organization's representatives involved in this project are also working together on another infrastructure project in which they have serious tension and conflicts. Presumably, some feelings have been transferred to the current collaboration that is affecting the collaborative relationship among parties. Based on the respondents, unsuccessful collaborative experiences adversely affect the trust between organizations, which is a key element of collaboration. A project leader believes that the lack of experience of one of the parties in IOC is also challenging because they might not have an appropriate vision and seek to realize their own goals rather than the collaborative goals, which is not desired in IOC.

Based on practitioners' perspectives possible challenges and issues of IOC are identified and summarized in Table 3.2. The list of challenges is ordered based on the number of respondents that mentioned that challenge ($\mathcal{F}$). The higher the value of $\mathcal{F}$, the more prominent the challenge.

Table 3.2. The challenges and issues of inter-organizational collaboration based on the respondents.

Challenges and issues of IOC	$\mathcal{F}$
Rules, guidelines, and organizational structure	12
Discrepancy of working attitudes in different infrastructure organizations	8
Different interests among organizations	7
Successive changes in a collaborative team	7
Disparity of professional languages and technical terminology	6
Lack of clarity about the interests and demands	5
Disunity among the collaborative team	4
Cultural differences	3
Dominant position of organizations	3
Pressure of parent organization	2
Unsuccessful previous experience	2
Monopolist position of organizations	1
No experience with inter-organizational collaboration	1

3.4. Discussion

Large-scale projects such as infrastructure projects are recognized as complex projects that require collaboration between different organizations (Jones & Lichtenstein, 2009; van Marrewijk, Ybema, Smits, Clegg, & Pitsis, 2016). The involvement of different organizations with various expertise, interests, cultures and structures increases the number of potential conflicts (van Marrewijk *et al*., 2016). To overcome these conflicts, the possible challenges and issues of IOC should be identified. Based on the results obtained from the case studies of inter-organizational interconnected infrastructure projects in The Netherlands, the challenges and issues of IOC are explored in the present work (see Table 3.2).

According to the respondents, the most mentioned challenge of IOC is the rules, guidelines, and organizational structure resulting from the policies and rules of infrastructure organizations. The policies and related rules of each organization build the structure of an organization and govern the important tasks and processes of organizations such as decision-making and required approval

processes in a project. The strictness of organizational policies of the collaborative parties negatively affects the performance of collaborative work in megaprojects (Flyvbjerg, Bruzelius, & Rothengatter, 2003; van Marrewijk & Smits, 2016). The strict governance of each organization provides less flexibility for the parties to deal with unexpected circumstances. According to the respondents, the variety of policies and rules of collaborative organizations, impede achieving agreement about all the tasks in an IOC. However, achieving an agreement between organizations is one of the factors of effective IOC (Kożuch & Sienkiewicz-Małyjurek, 2016).

The structure of organizations also influences the procedures and working attitudes in projects. The discrepancy of processes and procedures employed in different infrastructure organizations is the second most mentioned challenge in IOC. According to the practitioners, differences in the procedures and working attitudes disturb the alignment of parties, reducing the synergistic activities of the team. Creating common work attitudes and procedures in an IOC can enhance the synergy among collaborative parties. However, the monopolist position of some organizations, which are unwilling to change, hinders the creation of common collaborative processes.

According to the respondents, different work styles in IOCs can also be caused by cultural differences between different infrastructure organizations. Huxham *et al*. (2000) believe that the chance of misunderstandings and related conflicts among different collaborative parties can be increased due to the cultural differences between them. Cultural differences between different organizations negatively affect collaboration efficiency and collaborative parties' satisfaction (Vilana & Monroy, 2010). Therefore, understanding the culture and structure of other collaborative organizations and recognizing the differences results in mutual understanding (Suprapto, 2016).

Replacing team members within the structure of organizations and adding new members during the inter-organizational project are identified as one of the challenges that the respondents have faced. IOC involves different parties with various knowledge, skills, experiences, and perspectives. Therefore, changing a member of a party can increase the possibility of disagreements and conflicts in a collaboration. In addition, the knowledge built with predecessors drains due to successive changes in the team during IOCs.

Another most mentioned challenge according to the respondents is the variety of interests among organizations. Although the collaboration of different parties from various infrastructure organizations brings various perspectives and may provide new opportunities, it may also cause conflicts, as the interests of different parties are not necessarily identical. Existing different interests among organizations make it difficult to follow the same direction in collaborative work. According to van Marrewijk, Veenswijk, and Clegg (2014), fundamental differences in the interests of collaborative parties also can lead to fragmentation and adversarial relationships among the parties. To create an integrated collaboration, the different interests of each organization should be discussed and understood during the IOC.

Understanding each other during collaboration is one of the main factors of effective IOC (Kożuch & Sienkiewicz-Małyjurek, 2016). However, using different professional languages among various organizations complicates common understanding in a collaboration (Huxham *et al*., 2000). Using different terminologies and misinterpretations among the parties hinders proper communication during the collaboration, leading to misunderstandings and related conflicts between parties. A common understanding is necessary to create an integrated collaborative team and to gain collective agreement on the goals of a project (Ibrahim, Costello, & Wilkinson, 2011).

Differences in size and power of various infrastructure organizations are recognized as one of the issues in collaboration (Gray, 1990; Huxham *et al*., 2000). The dominant position of some organizations in IOCs is more notable in decision-making processes, leading to an increase in tension in IOCs. This challenge can be overcome by perceiving all the involved parties as one team. Being one team and blurring the organizational boundaries in IOCs enhances the collaborative relationship and quality of collaborative work (Hoegl & Gemuenden, 2001; Suprapto, 2016). However, losing the "we sense" during the collaboration and disunity among the collaborative parties is one of the potential challenges of respondents during the collaboration weakening the collaborative relationship.

One of the elements that affect an IOC is having a previous relationship with collaborative parties. Not all of the previous experiences of collaborative parties are successful. Experiencing conflicts or unsatisfied collaboration with certain parties reduces the trust among them and subsequently decreases the chance of a good relationship (Huxham *et al*., 2000) in future IOC. Even in the case of unsuccessful previous experiences among the collaborative parties, each collaboration should be considered as a new project and as a new attempt to build a relationship during the collaboration.

Based on the results and the discussions provided in the present work, the possible challenges and issues of IOCs are mostly related to the structure of each organization and the relationship between collaborative parties. The scientific contribution of this research is to identify the challenges and issues of IOC in interconnected infrastructure construction projects, which is less addressed in the literature. Additionally, this research assists the practitioners to predict and deal with the possible challenges and issues facing IOC and improves their collaboration.

3.5. Conclusions

The aim of this research was to explore possible challenges and issues in IOC based on practitioners' perspectives. To this end, case studies were conducted, and semi-structured interviews were performed with key participants in inter-organizational infrastructure projects in The Netherlands. Analyzing the results of the interviews, the challenges and issues that practitioners have faced in IOC were identified. The identified challenges and issues of IOC in interconnected infrastructure projects can be categorized into two dimensions: structural dimension and relational dimension.

Structural dimension is mainly related to rules, guidelines, and organizational structure, discrepancy of working attitudes in different infrastructure organizations, successive changes in a collaborative team, cultural differences, and monopolist position of organizations. Relational dimension is related to different interests among organizations, disparity of professional languages and technical terminology, the dominant position of organizations, disunity among the collaborative team, the pressure of parent organization, no experience with IOC, lack of clarity about the interests and demands, and unsuccessful previous experience. The two most mentioned challenges and issues of IOC are related to the structural dimension, which are rules, guidelines, and organizational structure and discrepancy of working attitudes among different infrastructure organizations. It shows that reforming the policies of infrastructure organizations in favor of collaborative policies and being more flexible in adapting the organizational structures and procedures to create a common collaborative structure can facilitate IOC in interconnected infrastructure projects.

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4

Inter-Organizational Collaboration in Interconnected Infrastructure Projects[3]

This study aims to identify which factors affect inter-organizational collaboration (IOC) in interconnected infrastructure projects to enable practitioners to establish a collaborative environment at the project level. This specific form of inter-organizational collaboration (IOC) that is characterized as "horizontal" has received limited attention in the literature. To this end, a systematic literature review and Q-methodology were conducted. The Q-methodology involves practitioners from various infrastructure organizations in the Netherlands gaining insights into their perspective on IOC in interconnected infrastructure projects. The study identifies two perspectives: a "holistic, goal-oriented" perspective that recognizes various dimensions of IOC, and a more "people-oriented" perspective that emphasizes the value of individual factors for IOC. The findings suggest that multiple perspectives on collaboration exist among practitioners, potentially affecting collaboration in interconnected infrastructure projects. Awareness of the need to manage practitioners' perspectives, and addressing and discussing these differences, can stimulate inter-organizational collaboration and contribute to improved project performance.

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4.1. Introduction

Critical infrastructures, such as energy, water, transportation, and IT-based services, play a crucial role in providing essential services to communities and businesses. This, in turn, drives economic growth and contributes to the advancement of society. However, many infrastructures are approaching the end of their technical or functional lifetime in many countries (Hertogh, Bakker, van der Vlist, & Barneveld, 2018). Hence, many infrastructures and their assets need to be replaced, upgraded, or developed to meet the requirements of sustainable growth and address upcoming environmental challenges.

The next generation of infrastructures is expected to cope with the entangled state of today's infrastructures, which often intersect, interconnect, or exist in close proximity to each other, particularly in urban areas. In these environments, a higher level of interdependence between infrastructure projects is anticipated, necessitating closer collaboration between infrastructure owners in such projects. For next-generation infrastructure projects, collaboration among infrastructure owners is not simply a preferred approach, but a fundamental requirement to address the challenges and uncertainties arising from these interconnections (Hall *et al*., 2014; Røsok, de Bruijne, & Veeneman, 2023), which requires new techniques, working methods and processes.

The interconnected nature of Infrastructures demands increased inter-organizational collaboration to address uncertainties (Hall *et al*., 2014; Newell & Swan, 2000). The existing literature on IOC recognizes that knowledge and resource sharing through collaboration stimulates multidisciplinary knowledge development and competencies among practitioners that cannot be obtained from individual organizations (Newell & Swan, 2000). Knowledge and resource sharing during collaborations also enables the development of innovative solutions for complex problems, which improves equity and lowers risk among collaborators, achieves more fruitful outcomes, and reduces reworking (Gray,

1990; Hardy & Phillips, 1998; Stout & Keast, 2021; Trist, 1983). Collaboration increases the possibility for synergy by bringing multidisciplinary parties together to share their knowledge and generate better outcomes in comparison with those produced in isolation (Emmitt & Ruikar, 2013) and produces flexibility through the combining and sharing of competencies (Mason, Lalwani, & Boughton, 2007).

However, despite the widely recognized benefits of IOC, there is also evidence that the full potential of collaboration is rarely reached (Franco, 2008; Madhok & Tallman, 1998; Nezami, de Bruijne, Hertogh, & Bakker, 2022a; Thomson & Perry, 2006). IOC is a formidable challenge, primarily due to the presence of conflicting interests between the participating organizations (Hardy *et al*., 2005; Nezami, de Bruijne, Hertogh, & Bakker, 2022b). In addition, organizations participating in IOC face problems that require significant efforts from various parties to resolve and are of a different kind and higher complexity than what they may encounter in their own organizations (Raišienė, Korsakienė, & Lace, 2015). Rigid organizational boundaries, poor communication, and lack of mutual understanding frustrate IOC (Foster-Fishman, Salem, Allen, & Fahrbach, 2001). To help improve collaboration and unleash its full potential, it is important to identify which factors affect IOC. The practical factors that contribute to collaboration seeking to stimulate joint working, joint decision-making and the solving of collective problems are often underrated and overlooked (Faris, Gaterell, & Hutchinson, 2019; Kożuch & Sienkiewicz-Małyjurek, 2016; Saukko, Aaltonen, & Haapasalo, 2020).

Construction literature primarily identifies factors that support collaboration within the construction supply chain (Akintoye, McIntosh, & Fitzgerald, 2000; Simatupang & Sridharan, 2005) and from the contractors' perspective (Akintoye & Main, 2007; Suprapto, Bakker, & Mooi, 2015). However, empirical research that identifies what factors contribute to collaboration between infrastructure

owners (*i.e.,* horizontal collaboration) in interconnected infrastructure projects has not yet been thoroughly addressed.

This research represents a novel endeavor in the identification and examination of critical factors that contribute to horizontal collaboration in interconnected infrastructure projects. Accordingly, this research contributes to both the conceptual and practical study of IOC. The methodology of this research consists of two parts: a systematic literature review and a Q-methodology. The literature review was performed to identify the underlying factors of horizontal collaboration in interconnected infrastructure projects, while the Q-methodology was used to elicit the perspectives of infrastructure practitioners on collaboration in such projects. The remainder of the paper is structured as follows: Section 4.2 outlines the research methodology, Section 4.3 presents the literature review, Section 4.4 explains the Q-methodology, Section 4.5 describes the results of the Q-methodology, Section 4.6 discusses the findings, and Section 4.7 concludes the study.

4.2. Research methodology

In search of a comprehensive overview of factors that contribute to IOC, three different sources of knowledge were used: academic literature, preliminary research on IOC in interconnected infrastructure projects and findings from a single case study of an interconnected infrastructure project in the Netherlands.

4.2.1. Literature study

The Scopus and Web of Science databases were searched to identify scientific literature that reports on the factors of inter-organizational collaboration from the year 2000 to 2020. The search terms used to identify potentially relevant publications included “Inter-organizational collaboration” OR “Horizontal collaboration” AND “Factor” OR “Indicator” OR “Element”. The search results were limited to (fields of study: management, engineering, and social sciences; Language: English; and type of document: journal articles). After this database

search, the results were filtered based on an analysis of the title and abstract. A second filtering was performed via a comprehensive review of the remaining articles. The literature review and analysis resulted in a shortlist of 10 papers, which altogether identified forty factors of IOC (see Table A2 in Appendices).

4.2.2. Preliminary research

A secondary source of factors of IOC was found through preliminary research conducted by the authors on the state of IOC in Dutch interconnected infrastructure projects (Nezami *et al*., 2022a). Practitioners with experience in interconnected infrastructure projects and IOC were interviewed to determine the factors that practitioners think contribute to collaboration. In total, 25 factors were mentioned (see Table A3 in Appendices).

4.2.3. Single case study

Interviews were conducted as part of a case study aimed at improving collaboration between two infrastructure owners in an interconnected infrastructure project in the Netherlands. Semi-structured interviews were held with practitioners in 16 key roles in cross-infrastructure project teams, who mentioned 29 factors of IOC (see Table A4 in Appendices).

4.2.4. Q-methodology

The lists of factors identified via the various sources were used as inputs for the Q-methodology study to investigate infrastructure practitioners' perspectives regarding the factors of IOC. Q-methodology is a generic research method that combines quantitative and qualitative techniques to explore the perspectives of respondents on specific issues or topics (McHugh, Baker, Biosca, Ibrahim, & Donaldson, 2019; Stenner, Watts, & Worrell, 2017). The implementation of Q-methodology is discussed in detail in section 4.

4.3. Literature review

An extensive list of factors was identified through an analysis of the literature data related to the factors of inter-organizational collaboration (IOC). However, to maintain conciseness, this study specifically discusses the critical factors of IOC that have been introduced in each study, while the complete list of factors can be found in Appendix A. The present section outlines the factors that were identified through an analysis of the relevant literature. These factors will be combined with those identified in practice. The resulting list of factors will serve as the input for a Q-methodology study, the findings of which will be discussed from the standpoint of infrastructure practitioners' perspectives. A comprehensive list of identified factors is provided in Appendix A, Table A1. Some of the previous studies have categorized these factors, and this study discusses these categories in detail.

Key factors

Verdecho, Alfaro-Saiz, Rodriguez-Rodriguez, and Ortiz-Bas (2012) consider top management support, leadership, shared vision, trust, and commitment to be critical factors of IOC. Jacobson and Choi (2008) identify open communication, commitment, and willingness to collaborate as key factors enhancing collaboration. These factors were among the ten factors that were identified as sources of collaboration, including the creation of a shared vision, commitment, communication, trust, willingness to collaborate, respect, political support, technical knowledge, shared pain and gain, and clear roles and responsibilities. In addition to shared vision, commitment, trust, and clear roles, Dietrich, Eskerod, Dalcher, and Sandhawalia (2010) claim that physical and cultural proximity, conflict resolution, and expectation fulfilment enhance IOC in multi-partner projects.

Smith and Thomasson (2018) and Savolainen, Saari, Männistö, and Kähkonen (2018) recognize communication as a key factor contributing to

collaboration. In addition to communication, factors such as shared vision, organizational culture, unity, commitment, and the early involvement of participants are identified to facilitate IOC (Faris *et al*., 2019; Smith & Thomasson, 2018). To establish a collaborative environment, Sujan, Wynford Jones, Kiviniemi, Wheatcroft, and Mwiya (2020) identify critical factors that are essential to enhancing collaboration. These factors include motivation, working relationships, leadership, communication, early involvement of participants, and an emphasis on the relational aspects of inter-organizational collaboration.

The abovementioned factors of IOC identified through the literature study were utilized as a knowledge source to conduct the Q-methodology. These factors are reported in Table A2 of Appendix A.

Categories of factors reported in the literature

Getha-Taylor (2008) argues that collaboration with other organizations creates public value and requires the development of specific individual collaborative skills such as interpersonal understanding, adaptability, and individual competency. Similarly, O'Leary, Choi, and Gerard (2012) argue that individual aspects determine whether IOC will be facilitated or hampered. O'Leary *et al*. (2012) present five categories: individual attributes, interpersonal skills, group process skills, strategic leadership, and the technical knowledge of collaborators. This, however, differs from the categories identified by Verdecho *et al*. (2012), which go beyond the individual domain and include strategy, culture, process and organizational structure. Faris *et al*. (2019) identify six categories of factors of IOC in construction projects: project vision, collaborators' behavior, communication, relationship definitions, agreements, and systematic process. Kożuch and Sienkiewicz-Małyjurek (2016) identify five categories of IOC factors including external environments, organizational characteristics, individual characteristics, relational factors, and instruments.

Finally, Kożuch and Sienkiewicz-Małyjurek (2016) claim that organizational characteristics and relational factors have the greatest influence on IOC.

The literature presents various categories of factors influencing IOC, some of which partially overlap. Despite the diverse terminology used to categorize these factors, they can be categorized into three broad themes or sets of characteristics: individual characteristics, the relationship between collaborators, and the structural and organizational aspects of IOC.

4.4. Q-methodology

The Q-methodology was conducted to study practitioners' perspectives on (factors of) IOC in interconnected infrastructure projects in the Netherlands via four subsequent steps (McKeown & Thomas, 2013): (1) the collection of the concourse and the Q-set; (2) the selection of respondents (P-set); (3) sorting of statements (Q-sort); and (4) the data analysis.

4.4.1. Concourse collection

The concourse is the collection of all relevant data about the subject of a study (Brown, 1993). The concourse in this research consists of a list of 47 factors of IOC from the three different sources of knowledge (see Section 2), which are listed in Table A1 in Appendix A.

A Q-set was extracted from the concourse. The Q-set contains 36 statements about the factors of IOC in interconnected infrastructure projects that were mentioned in at least two different sources of knowledge to reduce the size of the Q-set (see Table A1 of Appendix A). The list of Q-statements provided to respondents during the sorting process includes three categories to simplify the interpretation of various factors in practical settings: individual collaborative capacity (ICC), relational collaborative capacity (RCC), and organizational collaborative capacity (OCC), as presented in Table 3.1. The inclusion of these categories was a deliberate effort to aid respondents. It is important to note that

these categories cover the critical factors of inter-organizational collaboration (IOC) and are consistent with categories proposed in prior research, such as the categories proposed by Foster-Fishman, Berkowitz, Lounsbury, Jacobson, and Allen (2001).

Table 4.1. Q-set.

Category	Q-statement
Individual collaborative capacity (ICC)	1. Commitment
	2. Respect among people
	3. Willingness to collaborate
	4. Interpersonal understanding
	5. Understanding the mutual expectations
	6. Individual competency for collaborative tasks
	7. Professional and technical expertise of collaborators
	8. Previous inter-organizational collaboration experience
	9. Getting to know each other
	10. Having fun
	11. Relationship building
Relational collaborative capacity (RCC)	12. Unity with no organizational boundaries
	13. Early involvement of key participants
	14. Reciprocated Trust
	15. Openness
	16. Adaptability
	17. Common goal and shared vision
	18. Inclusive coordination and teamwork
	19. Joint decision-making
	20. Management via a common collaborative process
	21. Equality between collaborating parties
	22. Balanced relationship
	23. Shared organizational culture
	24. Understanding of different organizational culture
Organizational collaborative capacity (OCC)	25. Collaborative leadership
	26. Top management support
	27. Frequent, high-quality, professional communication
	28. Direct informal communication
	29. Safe environment
	30. Resource sharing
	31. Clear definition of roles and responsibilities
	32. Collaborative legal agreement
	33. Collaborative common ground rules
	34. Collaborative tools and technologies
	35. Regulations and government support
	36. Share pain and gain

4.4.2. P-Set

The second step of the Q-methodology concerns the selection of respondents (P-set) (McKeown & Thomas, 2013). To gain various perspectives, 15 respondents from different infrastructure organizations with varying functions and degrees of experience (from 10-40 years) in IOC in the Netherlands were selected to conduct the Q-sorting. Table 4.2 presents a summary of the respondents' functions in the present work.

Table 4.2. An overview of the respondents' functions in this study.

Function	Number of respondents
Project director	3
Project manager	3
project control manager	3
Technical manager	2
Developer	2
Senior manager	1
Stakeholder manager	1

4.4.3. Q-sorting

The next step in Q-methodology is the actual Q-sorting. Statements that contain factors from the Q-set (Table 4.1) are placed on individual cards, and the respondents are invited to sort them on a scale from "Totally disagree" (−3) to "Totally agree" (+3) on a seven-column grid (the scoreboard) representing a quasi-normal distribution (see Figure 4.1).[4]

[4] The respondents were asked "*Which are the most or least important factors for inter-organizational collaboration in interconnected infrastructure construction projects?"* and subsequently invited to sort the Q-statements on the scoreboard according to their preference.

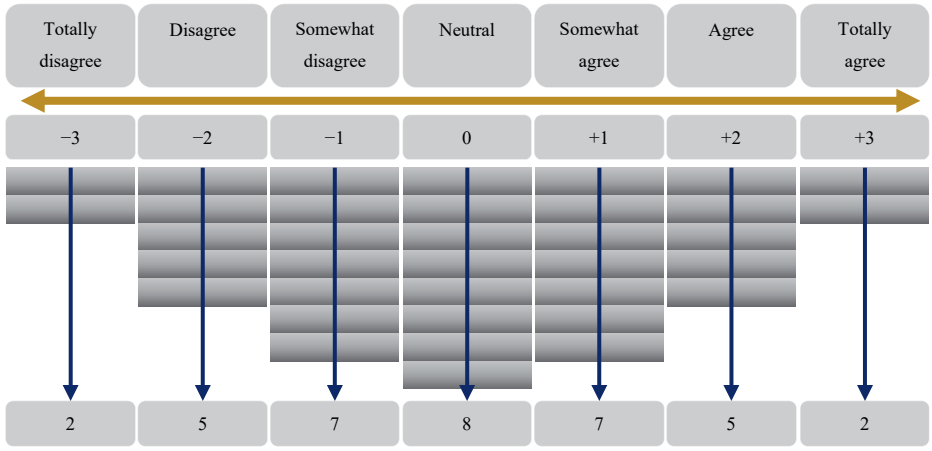

Figure 4.1. Scoreboard for Q-sorting.

As the research was conducted under COVID-19 restrictions, which hampered face-to-face contact, the Q-set was shared electronically with the respondents for sorting using an online platform (www.qsortware.net). During the meeting, respondents were guided through the Q-sorting process via stepwise sorting instructions. Sorting took place in two steps. First, respondents were asked to allocate statements to one of the three columns, Disagree, Neutral, or Agree, without posing any restrictions (Watts & Stenner, 2012). The second sorting step consisted of inviting the respondents to place the statements from the three columns on the scoreboard (Watts & Stenner, 2012) (see Figure 4.1). During and after the sorting process, the respondents are asked to explain their sorts, and follow-up questions are asked to clarify the respondents' actions (*e.g.,* why they placed certain statements somewhere in the three columns or on the Q-sorting scoreboard).

4.4.4. Data analysis

In the final step of the Q-methodology, the completed sorts of the respondents are analyzed. First, a factor analysis is conducted to identify correlations between the sorting of the individual statements of the respondents. Next, the results of

the factor analysis are analyzed to extract a number of perspectives, which, in essence, assesses the key sorting patterns of the respondents (*i.e.* the level of similarity of every Q-sort generated by the P-set).

The PQ-Method 2.35 program was used to conduct the data analysis. There is no correct number of factors, and the researcher can decide how to analyze the sorting based on the following criteria. How many meaningful factors to include in the analysis is decided based on two parameters (Brown, 1993): (1) the cumulative percentage of explained variance is more than 50%, and (2) the highest two-factor loadings should at least be equal to 2.58 times the standard error (SE), which is equal to $2.58\frac{1}{\sqrt{N}}$, with *N* being the number of statements equal to 36. Based on the mentioned parameters two, three, or four perspectives can be extracted.

Next, the criteria introduced by Webler, Danielson, and Tuler (2009) are used which are simplicity, clarity, distinctness, and stability. In comparison with other factor solutions, a two-factor solution is simpler; with a smaller number of perspectives, it is clearer; no non-loaders occur; and it is more stable, as the perspectives extracted have a higher number of loaders. In this research, a two-factor extraction solution was thus decided upon. Based on analysis of the results of the Q-sorting and the interviews with the respondents, two distinct perspectives were labeled as follows: Perspective 1: holistic goal-oriented and Perspective 2: people-oriented. Two perspectives with nine and six loaders are shown with Z-score and Q-score values in Table A5 of Appendix A. These two perspectives are discussed in Section 5.

4.5. Results

4.5.1. Perspective 1 (Holistic Goal-Oriented)

The first perspective was labeled as holistic goal-oriented. Nine respondents loaded on the first perspective accounting for 28% of the explained variance. The

factor scores of the top seven and bottom seven statements for this perspective are depicted in Figure 4.2. The factor is distinguished at $p < 0.01$.

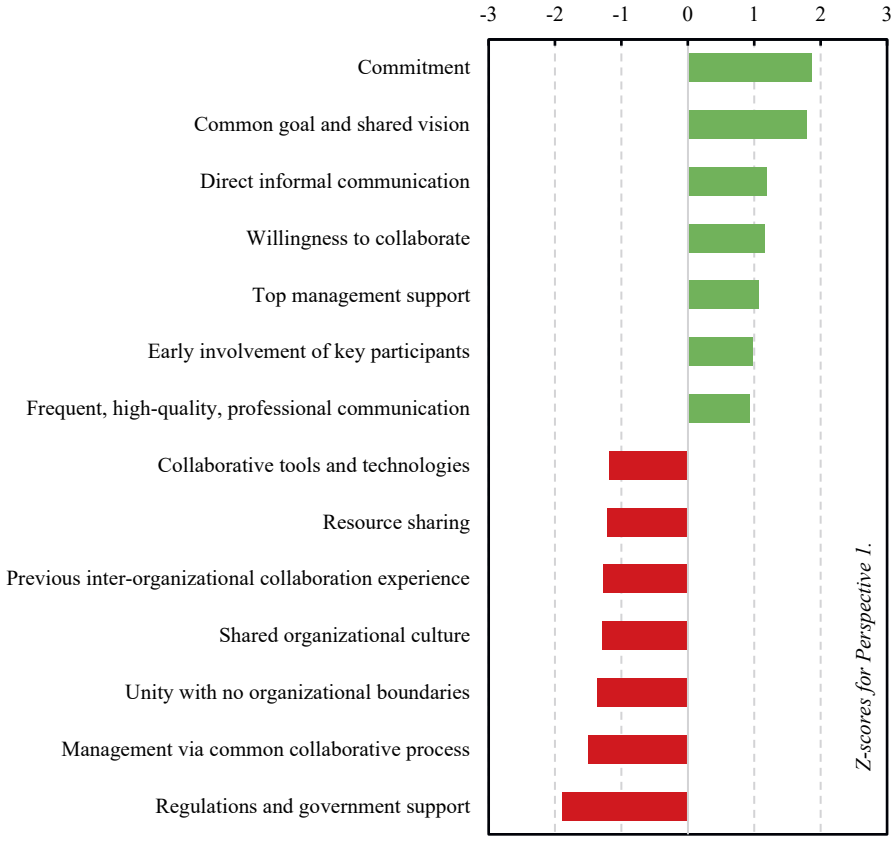

Figure 4.2. Perspective 1.

According to this group of respondents, the most important factors of IOC are *commitment* (+3) and *common goals and shared vision* (+3). They believe that the commitment of organizations leads to achieving the best outcome in IOC: *"In the word commitment I see a lot of things, I see that you want to build a relation, want to be understanding, want to communicate, you are doing everything in your power to succeed"*. The respondents also state that without a

common goal and shared vision among the collaborators, there will be no collaboration. However, it does not mean that organizations cannot pursue their own goals. They can align their own goals to benefit from IOC: "*You can have your own goals, but the common goal is always the main goal holding the collaborating parties together*". A respondent adds that "*If organizations need similar things and have a shared vision they will collaborate and find a common solution for a common project*".

Another factor that is reflected in this perspective is (formal and informal) communication (+2). The respondents emphasize the importance of informal communication and consider that it also influences other factors of IOC such as trust and interpersonal understanding: "*Informal communication is essential to build the relationship, it can help to create a better understanding between organizations and build trust among them*". Furthermore, the respondents believe that formal and informal communication facilitates data sharing between infrastructure organizations and leads to efficient decisions in IOC. It is also worth noting that there exists a potential relationship between the identified factors of IOC. According to the respondents, enhancing communication has the potential to improve mutual trust and understanding within a collaborative team.

The group of respondents making up this perspective further believes that *regulations and government support* and *management via a common collaborative process* (−3) are not critical for IOC and can function without these factors. The respondents emphasize this by pointing out that "*every infrastructure organization has its own management and processes and can work on its own parts of the project with its own processes, while IOC can still work*".

4.5.2. Perspective 2 (People-Oriented)

Six respondents loaded on the second perspective, which is labeled people-oriented, accounting for 23% of the explained variance. The characterizing

statements (top seven and bottom seven) of the second perspective are shown in Figure 4.3.

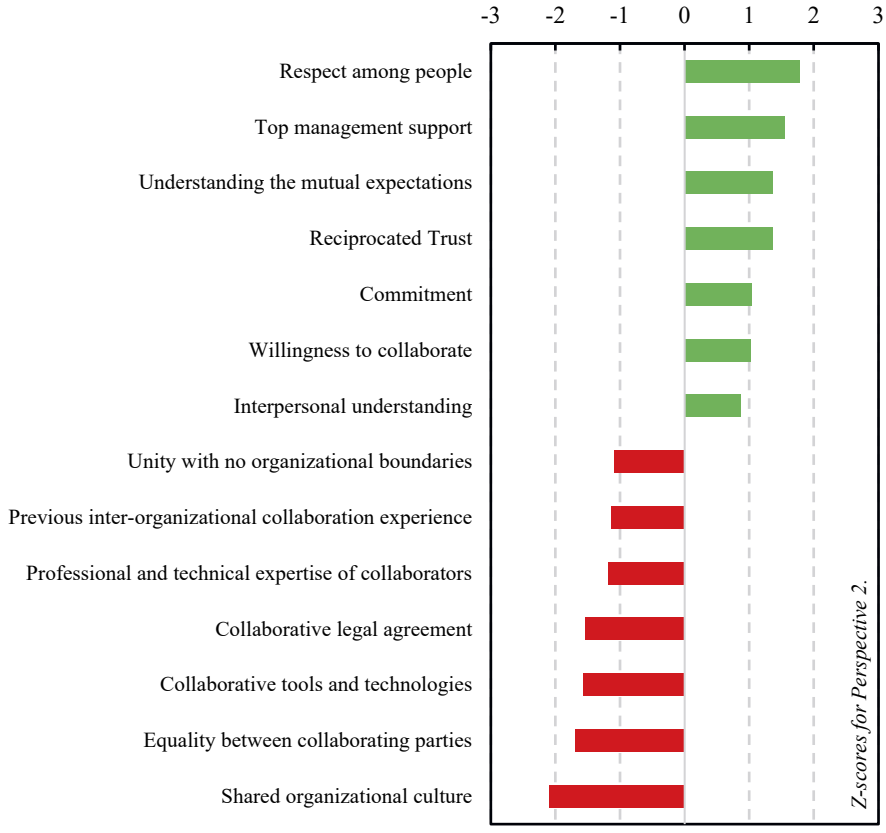

Figure 4.3. Perspective 2.

The highest-ranking factors in the second perspective are *respect among people* (+3) and *top management support* (+3). The respondents stress that *respect among people* is of key importance throughout the whole project and can prevent potential conflicts. The respondents also consider *top management support* essential for IOC and the achievement of results: "*The desired results will not be reached without the support of the top management*".

Understanding mutual expectations (+2) is also considered an important factor of IOC. "*Especially in the beginning you should be clear on what you expect from each other*", states one respondent since each organization has its own interests and expectations, which are the triggers for joining a collaborative project. According to the group making up Perspective 2, *reciprocated trust* (+2) is important because it enhances the relationship between the organizations and facilitates collaboration: "*You should work to earn the trust of other parties so that you go on further in the project*". The respondents believe that a lack of trust affects the whole relationship and creates conflict in IOC.

Equality between collaborating parties (−3) and *shared organizational culture* (−3) are not considered necessary as building blocks of IOC according to this perspective. A respondent expresses that "*it is a fact that inequality exists. Sometimes hierarchy between organizations is needed for proper functioning in IOC*". This group also declares that lack of shared organizational culture is generally not an issue in IOC: "*Organizational culture is never an issue when you understand each other*". One respondent adds that "*we are professionals and need to accept that each organization has its own culture*".

4.5.3. Comparison of perspectives

The similarities and differences between Perspectives 1 and 2 are not all that large. Among the seven highest-ranked statements, three of them are similar in both perspectives (*commitment*, *willingness to collaborate*, and *top management support)*. Four of the seven lowest-ranked statements are also present in both perspectives (*collaborative tools and technologies, previous inter-organizational collaboration experience, shared organizational culture and unity with no organizational boundaries).*

The most distinguishing statements between the first and second perspectives are *direct informal communication* (+1.89) and *regulations and government support* (−2.53). According to the group of respondents in Perspective 1,

informal communication is critical for IOC; but not so much for those loading on the second perspective, while *regulations and government support* are advocated by respondents loading on the second perspective and not by those loading on Perspective 1.

Respondents loading on Perspective 1 ranked *informal communication* as the third highest statement. They see *informal communication* as a facilitator or indirect contributor to other factors of IOC. However, respondents belonging to the group who load on Perspective 2 ranked *direct informal communication* as the 27th statement, which is on the negative side of the Q-sorting bell shape.

In this study, two distinct perspectives were identified regarding the factors influencing the implementation of inter-organizational collaboration (IOC). The first perspective is characterized by a holistic approach that encompasses factors embedded in all three categories of IOC: individual (ICC), relational (RCC), and organizational (OCC) collaborative capacities. This perspective suggests that a comprehensive view of IOC is necessary to effectively implement it. Additionally, the respondents in the study exhibited a heightened commitment to IOC when a clear common goal was established. As a result, this perspective is labelled “holistic goal-oriented”.

The second perspective, however, primarily emphasizes the individual dimension of IOC, although it does not prioritize informal communication. This approach is labeled as “people-oriented” and centers around fostering respect and mutual understanding between individuals to establish effective interpersonal relationships. The focus is on developing an understanding of mutual expectations and interpersonal dynamics. This perspective is best described as centered around developing an interpersonal understanding to establish a collaborative environment. The second perspective emphasizes the importance of individual-level factors in achieving a successful IOC. This perspective recognizes that people play a crucial role in shaping the outcomes of

IOC and that their attitudes, behaviors, and skills can either facilitate or hinder the collaborative process. Therefore, this perspective emphasizes the need to develop an interpersonal understanding among the participants, which can be achieved through formal communication channels, such as meetings, reports, and agreements.

4.6. Discussion

Performing the Q-methodology in this research enabled the development of two perspectives: the holistic goal-oriented perspective with nine respondents loading on it and the people-oriented perspective with six loaders. The holistic goal-oriented perspective assumes that IOC requires the presence of factors from all three categories. The most important factors of IOC in the holistic goal-oriented perspective are *commitment* and *common goal and shared vision*. These factors are also mentioned with high frequency in the literature. Setting a common goal and shared vision is considered a key factor in establishing a collaborative environment (Faris *et al*., 2019), and commitment is mentioned as an essential factor of IOC (Smith & Thomasson, 2018). Commitment, which is essential for collaboration, drives involvement from all participants, ultimately leading to the accomplishment of the agreed-upon goals (Jacobson & Choi, 2008).

The holistic goal-oriented perspective, unlike the second perspective, emphasizes the importance of formal and informal communication. Communication enhances collaborative relationships and information sharing, which, in turn, are required to achieve common goals. According to Perspective 1, the majority of information that needs to be exchanged occurs through informal communication, which facilitates IOC. Communication and interaction between collaborators are considered simple and effective tools to transfer information, maintain relationships (Sujan *et al*., 2020), and improve workflows in IOC (Savolainen *et al*., 2018). Sujan *et al*. (2020) emphasize that

informal communication enhances collaborative projects. A form of informal communication such as personal dialog, benefits practitioners by allowing them to develop a mutual understanding and enabling them to quickly solve practical issues (den Otter & Emmitt, 2008). It indicates the presence of a potential relationship between communication and interpersonal understanding in IOC.

Perspective 1 prioritizes the mutual management of a collaborative project and values factors such as a *common goal and shared vision*, *informal communication*, and w*illingness to collaborate* as important factors of IOC. However, this perspective does not advocate for resource sharing, having common processes, and unity among the parties in IOC. It seems that there is a tendency to focus on one's own organization and its procedures rather than the common and collaborative ones. Verdecho *et al*. (2012) argue that although each organization in the collaboration maintains its own structure and procedures, an inter-organizational structure and common procedures need to be developed to facilitate collaboration in complex projects.

The people-oriented perspective focuses on the individual aspects of IOC, such as *respect among people*, *understanding mutual expectations*, *commitment*, *willingness to collaborate,* and *interpersonal understanding*. The individual skills of employees who engage in collaboration, relationships with individuals in the IOC, understanding mutual interests, and sharing the individual expectations of the collaboration are considered fundamental to accomplishing a collaborative project (Huxham & Vangen, 2000; O'Leary *et al*., 2012). Respecting each other and understanding each other's opinions helps to build a collaborative environment in which support, mutual goal setting, and shared achievements can feature (O'Leary *et al*., 2012). It is remarkable that informal communication is not appreciated by the respondents loading on Perspective 2 even though they consider mutual and interpersonal understanding important factors of IOC. To enhance mutual understanding among organizations informal communication is considered beneficial (den Otter & Emmitt, 2008).

The group making up the second perspective advocates top-management support and government support, which indicates that this perspective recognizes the importance of external support to organizing and improving IOC. This perspective favors a hierarchical structure and governmental policies to facilitate IOC. Jacobson and Choi (2008) also argue that political regulations can serve to improve IOC when conflicts or disagreements arise between the parties. However, Phillips *et al*. (2000) believe that IOC is a collaborative relationship without "*hierarchical mechanisms of control*". There is a need to find a balance between self-governance, where the parties collaborate to formulate their own collective solutions, and hierarchical governance (Kooiman, 2003).

Both perspectives can coexist in a collaborative project. Advocates of Perspective 1 prefer to jointly manage the project and communicate informally to achieve common goals; while advocates of Perspective 2 value individual characteristics in the collaboration and prefer hierarchical and governmental support to achieve success in IOC.

The differences in these perspectives could help explain why collaboration in construction projects is so hard to achieve. Misunderstanding can exist between individuals in collaborative projects because individuals seem to have diverging ideas about what is required for collaboration, and this may even result in conflicts in the collaboration. However, being aware of the differences and openly sharing viewpoints on collaboration at the early stages of it (when the project team is formed) can enhance mutual understanding in collaboration (Savelsbergh & Storm, 2014) and can be considered an opportunity for collaborators to inform and complement each other. Learning which perspectives are present among the members of a collaborative project can contribute to synergy in IOC. During the formation of the project team, the team can discuss preferred ways of working, share attitudes toward collaboration and discuss differences in their perspectives to develop an agreement on how to collaborate and facilitate the process of collaboration (Savelsbergh & Storm, 2014).

Another point of discussion is the commonality of low-ranked statements, such as shared organizational culture, management via a common collaborative process, unity with no organizational boundaries, and collaborative tools and technologies. These factors are signs of creating one project organization with common processes and procedures. The research findings suggest that practitioners prefer to perform a common project primarily on their own and based on their own processes. Disunity between the collaborators, the use of different processes and procedures, and cultural differences could be identified as potential challenges that can hinder effective IOC (Nezami *et al*., 2022b). O'Leary *et al*. (2012) also argue that collaboration encounters difficulties due to differences in goals, cultures, procedures, and processes. A shared organizational culture improves collaborative learning, satisfaction and communication between the parties in IOC (Sirmon & Lane, 2004). Shared organizational culture can be developed by working across organizational boundaries and being a united team (Smith & Thomasson, 2018). Unity and a collaborative spirit between the parties increase the quality of IOC (Dietrich *et al*., 2010; Suprapto, 2016). Therefore, creating an integrated project team with common processes and procedures and a shared culture can overcome potential challenges and facilitate IOC.

4.7. Conclusions

Realizing interconnected and interdependent infrastructure projects in a dynamic environment requires that infrastructure operators combine multidisciplinary knowledge and rely on collaborative skills to achieve IOC. This study identifies factors of IOC that can enable practitioners to establish a collaborative environment to work on the realization of interconnected infrastructure projects. The factors of IOC are identified through the literature study and performing a Q-methodology. This study utilized a Q-methodology study to analyze the factors of inter-organizational collaboration (IOC) in the context of interconnected infrastructure projects.

The results of the study suggest that shared organizational culture, management via a common collaborative process, and unity without organizational boundaries are viewed by practitioners as relatively low-significance factors in inter-organizational collaboration for interconnected infrastructure projects. However, previous studies have highlighted that differences in cultures, processes, and procedures between infrastructure owners can be potential obstacles to successful collaboration. This prevalence of fragmented practices among infrastructure owners suggests a siloed mentality that prioritizes individual procedures over integrated and collaborative approaches. Further research is needed to gain a deeper understanding of the role and impact of these factors on inter-organizational collaboration in interconnected infrastructure projects.

The Q-methodology revealed two distinct perspectives: the holistic goal-oriented perspective and the people-oriented perspective. The holistic goal-oriented perspective emphasized the importance of formal and informal communication between collaborators and incorporated factors from all three categories of collaborative capacity (individual, relational, and organizational). The people-oriented perspective prioritized the individual dimension of IOC and highlighted the significance of top management and government support in facilitating the realization of joint infrastructure projects. These perspectives provide valuable insights into the multifaceted nature of inter-organizational collaboration in the context of infrastructure projects.

No one perspective is inherently superior to the other, and both can exist within project teams. Therefore, the managerial implication of this study is that practitioners involved in interconnected infrastructure projects should acknowledge the existence of diverse perspectives on collaboration and their potential impact on it. To achieve synergistic collaboration within a project, it is important to effectively manage different perspectives and consider them complementary. This requires a deep understanding of the differences between

the practitioners' perspectives on collaboration and the ability to create a collaborative environment that considers various factors contributing to successful inter-organizational collaboration. The main building blocks of inter-organizational collaboration (IOC) were identified through the high-ranked statements across the perspectives. These building blocks include commitment, respect among people, common goals and shared vision, and top management support. These factors can be leveraged to promote effective collaboration and achieve common goals in an infrastructure project.

In this study, the background information of the practitioners was noted, such as years of working experience and roles in infrastructure organizations. The findings indicate that the identified perspectives are independent of years of experience and the roles the respondents perform. We recommend conducting further investigations into this relationship.

Based on the preliminary findings of the present study, it has become evident that the identified factors of inter-organizational collaboration (IOC) have the potential to influence one another. While this suggests the existence of a complex and dynamic system, it also underscores the need for further research to establish a comprehensive and robust relational model between these factors. To this end, future research could aim to examine the causal links between the various factors of IOC, as well as the magnitude of their effects on one another. Specifically, such research could seek to identify the specific mechanisms through which these factors interact, including the mediating and moderating variables that may be at play. Additionally, the study could investigate how different contextual factors may shape the relationships between the various factors of IOC.

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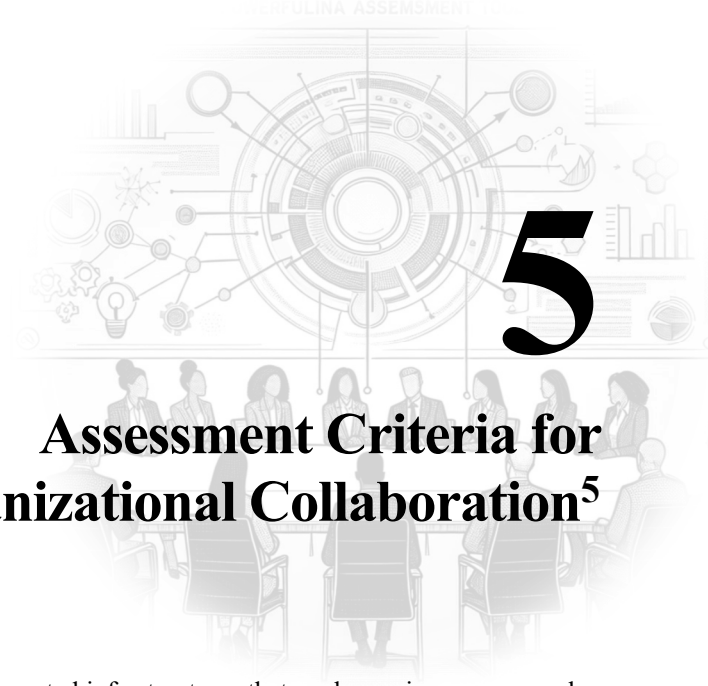

5

Assessment Criteria for Inter-organizational Collaboration[5]

Societies depend on interconnected infrastructures that are becoming more complex over the years. Multidisciplinary knowledge and skills are essential to develop modern infrastructures, requiring close collaboration of various infrastructure owners. To effectively manage and improve inter-organizational collaboration (IOC) in infrastructure construction projects, collaboration status should be assessed continually. This study identifies the assessment criteria, forming the foundation of a tool for assessing the status of IOC in interconnected infrastructure projects. A systematic literature study and in-depth semi-structured interviews with practitioners in interconnected infrastructure construction projects in The Netherlands are performed to identify the criteria for assessing the status of IOC in infrastructure construction projects, based on which an assessment tool is developed. The identified assessment criteria through the literature and the practitioner's perspectives result in the designing and development of a collaboration assessment tool. The assessment tool consists of 12 criteria and 36 sub-criteria from three different categories of collaborative capacity: individual, relational, and organizational. The assessment tool enables practitioners to monitor the status of IOC between infrastructure owners and assists them in making informed decisions to enhance collaboration. The assessment tool provides the opportunity to assess and analyze the status of collaboration based on three categories (*i.e.,* individual, relational, and organizational).

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5.1. Introduction

The construction industry including the infrastructure sector prominently enhances various aspects of society such as the economy, safety, and environment (Grafius, Varga, & Jude, 2020; Yong and Mustaffa, 2012). Infrastructures as the main part of the construction industry provide essential services for society and serve as a vital foundation for promoting economic growth (Gondia, Ezzeldin, & El-Dakhakhni, 2022; Hatem, Kassem, Ali, & Khoiry, 2022). The proper development and functioning of various critical infrastructures are essential for ensuring societal welfare (Laugé, Hernantes, & Sarriegi, 2015).

The intricate and dynamic nature of infrastructures presents a continuous challenge to their design, development and exploitation, principally because they face various obstacles such as ageing, natural and technological disasters, and limited resources (Croope & McNeil, 2011; Hertogh, Bakker, van der Vlist, & Barneveld, 2018). The challenges encountered by infrastructure systems, specifically in relation to the ageing process, emphasize the necessity of implementing measures aimed at their development, upgrading, and replacement. However, the next generations of infrastructures are becoming more complex due to the continuous advancement of new technologies (Grafius *et al*., 2020; Organek John, 2017). Moreover, infrastructures are becoming strongly interconnected (*e.g.,* road and railway infrastructure crossing waterways) and can affect each other's performance directly (Carhart, Ersoy, Taylor, & Beigi, 2018; Rinaldi, Peerenboom, & Kelly, 2001). Consequently, global challenges, such as climate change, pandemics, and population growth, can impact interconnected infrastructures and lead to a potential cascade of failures (Grafius *et al*., 2020; Pamidimukkala, Kermanshachi, Adepu, & Safapour, 2021). Therefore, it is crucial to ensure that these complex and interconnected infrastructures are developed in a resilient manner to tackle both current and future challenges.

Interconnected infrastructures are considered, in the present study, as a bilateral relationship, wherein each infrastructure exerts a reciprocal influence upon the other. Despite the strong interdependencies between infrastructures, the development of infrastructures has often been executed relatively independently in silos (Carhart *et al*., 2018; Grafius *et al*., 2020). Additionally, the literature addressed the unsatisfactory performance of infrastructure projects, revealing that significant proportions of projects within the infrastructure sector fail to meet their intended budget and/or schedule (Cantarelli, Oglethorpe, & van Wee, 2022; Edwards, 2021; Eriksson, Larsson, & Pesämaa, 2017; Lo, Zhang, Ye, & Cui, 2022). The complex interdependence and dynamic characteristics of interconnected infrastructure projects make them particularly challenging and risky to manage (Gondia *et al*., 2022). Moreover, developing resilient interconnected infrastructures requires significant resources, substantial budgets, diverse set of specialized and multidisciplinary skills, which cannot be accomplished by working individually (Emmitt & Ruikar, 2013; Gondia *et al*., 2022; Pamidimukkala *et al*., 2021). Therefore, it can be argued that multidisciplinary collaboration across infrastructure organizational boundaries is essential to manage interconnected infrastructure projects (Grafius *et al*., 2020).

The management of interconnected infrastructure projects is challenging, requiring the coordination of tasks, and the application of multidisciplinary knowledge and skills from various infrastructure owners (Grafius *et al*., 2020; Nezami, de Bruijne, Hertogh, & Bakker, 2022). The chance to enhance the efficiency and resilience of infrastructures largely hinges on establishing collaboration between infrastructure owners (Eriksson *et al*., 2017; Grafius *et al*., 2020). Next-generation interconnected infrastructures are expected to require even closer collaboration between infrastructure owners to tackle the challenges of more integrated construction projects during their design, development, implementation, and management of the projects (Eriksson *et al*., 2017; Organek John, 2017).

Collaboration between different infrastructure organizations, in other words, inter-organizational collaboration (IOC), promises to optimize the efficiency of infrastructure construction projects. IOC enables these organizations to overcome the scarcity of resources and lack of competencies during the project (Dietrich, Eskerod, Dalcher, and Sandhawalia, 2010; Eriksson *et al*., 2017) and gain core values and potential benefits (Keung and Shen, 2013). IOC across national, cultural and political boundaries is considered even more essential in large-scale projects (*e.g.,* infrastructure projects) to cope with high degrees of uncertainty and complexity (van Marrewijk, Ybema, Smits, Clegg, and Pitsis, 2016). The present work focuses specifically on the horizontal collaboration between various infrastructure owners as IOC. "Horizontal collaboration" in this research can be defined as a synergistic relationship between two or more independent organizations with an equal distribution of power that work jointly to pool resources and knowledge towards the attainment of a shared goal, resulting in mutual benefits.

The success of complex infrastructure projects heavily relies on the quality of collaboration between infrastructure organizations (Kokkonen & Vaagaasar, 2018). Emmitt and Ruikar (2013) argue that "the better the collaboration, the better the outcome of the project". However, collaboration is not a straightforward process and can be challenging to achieve, especially in complex construction projects (Faris, Gaterell, & Hutchinson, 2019; Nezami *et al*., 2022). More often than not, lack of close collaboration, poor communication, and deficient participation from team members are identified which necessitates an increased capability of assessing collaborative practices and promoting measures to facilitate IOC (Faris *et al*., 2019; Ibrahim, Costello, and Wilkinson, 2011). Thus, more attention to the design of the collaboration as well as assessment of IOC during a project can assist practitioners with realizing collaboration and potentially enhance the performance of collaborative projects. Accordingly, an increased capability to design (*ex-ante*), assess and evaluate (*ex-post*) IOC by

tracking the status of the collaboration using recorded pieces of evidence is considered a critical component of managing collaborative projects. To this end, assessment tools need to be developed to assess IOC. They provide an overview of collaboration and enable practitioners to discover the strengths and weaknesses of the specific IOC. Marek, Brock, and Savla (2015) claim that the identification of the strengths and weaknesses of IOC via an assessment tool can contribute to effective collaborations. Moreover, the outcomes of collaboration assessments can assist practitioners and policy-makers in efficient decision-making (Thomson, Perry, and Miller, 2009). However, collaboration between various organizations (*i.e.,* horizontal collaboration) and identifying the criteria and providing the assessment tool for IOC in infrastructure construction projects is understudied (Hetemi, Ordieres, & Nuur, 2022; Keung and Shen, 2013; Longoria, 2005; Parung and Bititci, 2008).

The present work focuses on horizontal collaboration between various infrastructure owners and aims to identify IOC assessment criteria for interconnected infrastructure construction projects to design an inter-organizational collaboration assessment tool (ICAT). To this end, firstly, a literature study was carried out to assess IOC in construction projects and identify assessment criteria, and secondly, in-depth interviews were performed to collect practitioners' opinions on how to assess the collaboration between different infrastructure owners. Further details of these two approaches are explained in Section 5.2. Section 5.3 presents the literature review; Section 5.4 explains the results of in-depth interviews. Section 5.5 discusses the findings and the tool development. Finally, the concluding remarks In Section 5.6 highlight how utilizing ICAT would contribute to enhancing IOC in infrastructure projects.

5.2. Research methodology

Qualitative research was performed to identify criteria to assess the status of IOC in infrastructure construction projects. The research was conducted in two subsequent steps: (1) a systematic literature review was conducted to identify assessment criteria to develop a conceptual assessment tool and (2) an inter-organizational assessment tool (ICAT) was developed and refined based on the practitioner's perspectives.

5.2.1. Systematic literature review

A systematic review of empirical studies was performed to identify the criteria to assess IOC in the construction industry. This list of criteria was used as a basis for the development of the ICAT. To perform the systematic literature review, the Scopus and Web of Science databases were searched to retrieve relevant articles from the last 20 years. The search used keywords and Boolean operators such as: "Inter-organizational collaboration" OR "Horizontal collaboration" OR "Collaborative relationship" AND "Criteria" OR "Indicator" AND "Assessment" OR "Evaluation" OR "Measurement". The combination of these keywords was used as a starting point. A number of filters were applied (fields of study: management, engineering, and social sciences; language: English; and type of document: articles), which resulted in one hundred and ten papers. Initially, the titles and abstracts of these articles were screened to select relevant papers that specifically addressed the assessment of collaboration between different organizations. Articles focusing solely on specific aspects of a collaborative project without addressing collaboration assessment were excluded, reducing the number of articles to eighteen. Further examination of these eighteen articles revealed that some in the field of health management focused on collaboration assessment, but primarily in the context of inter-professional collaboration, such as the consistent collaboration between physicians and nurses to improve patient outcomes. Since inter-professional

collaboration between individuals fell outside the scope of our study, these articles were also excluded, resulting in a final selection of seven articles. The main objective of the present study is to assess collaboration between different organizations, particularly within the construction industry where infrastructure owners engage in "horizontal collaboration". Accordingly, four articles were identified that specifically addressed the assessment of horizontal collaboration between organizations. This literature selection formed the basis for the list of criteria to assess IOC. Based on our previous study (Nezami, de Bruijne, Hertogh, & Bakker, 2023) the identified criteria were categorized into: individual collaborative capacity (ICC), relational collaborative capacity (RCC), and organizational collaborative capacity (OCC).

5.2.2. In-depth interviews

Because studies of collaboration between different asset owners in infrastructure construction projects are scarce and an assessment tool for cross-infrastructure collaboration was missing (Keung and Shen, 2013; Longoria, 2005; Parung and Bititci, 2008), a practical assessment tool had to be built by making use of practitioner's perspectives. To this end, in-depth interviews were performed to gain insight into practitioners' perspectives on IOC and how to assess the status of collaboration between infrastructure owners. The interviews were used to check the criteria identified via the literature study from the previous step and develop the ICAT.

The main data collection method employed involved conducting semi-structured interviews. These interviews were carried out with individuals actively engaged in inter-organizational collaboration (IOC), as detailed in Table 5.1. The participants included practitioners from diverse infrastructure organizations, spanning various roles and possessing a range of experience levels, ranging from fifteen to thirty-three years. A total of twenty practitioners were interviewed. During the interviews, the respondents were asked to list their

criteria for assessing the status of IOC. This was done to complement the criteria identified in the literature. Next, the conceptual assessment tool was presented to the respondents, and they were asked to rank the importance of identified criteria from the literature based on a Likert scale (1: Very unimportant, 2: Somewhat unimportant, 3: Neutral, 4: Somewhat important, and 5: Very important). Accordingly, the results of the ranking for the importance of each criterion for IOC assessment were collected and analyzed statistically including the minimum, maximum, mean, and standard deviation values. Additionally, the respondents were asked to express their opinions about their ranking for each criterion. Each interview took approximately one hour and was recorded and transcribed. To analyze the interview results and accomplish the research objective, a qualitative-interpretive approach was selected (O'Connor & Gibson, 2003). The interview transcripts were summarized manually to capture principal insights based on key terms relevant to the main themes (collaboration, the inter-organizational context, and assessment). For confidentiality purposes, the names of the respondents are kept anonymous.

Moreover, given that the respondents were drawn from various infrastructure organizations with different functions, an additional analysis was also conducted based on their functions. To this end, the respondents were divided into two groups: senior level (N = 9) and project team (N = 11), as indicated in Table 5.1, to investigate possible differences in their opinions regarding the identified criteria. For this purpose, an independent samples Mann-Whitney test on the distributions of the scores of the identified criteria from the literature was performed. Since the data is based on Likert scales (ordinal data), it may not follow a normal distribution. Therefore, the Mann-Whitney U test is appropriate for comparing independent samples which is a nonparametric test that does not assume normality (Field, 2024; MacFarland, Yates, MacFarland, & Yates, 2016).

Table 5.1. Overview of the functions of the respondents interviewed in the present work.

	Function	Number of respondents
Senior level	Project manager	5
	Project director	2
	Members of the steering committee	2
Project level	Advisor	2
	Technical manager	2
	Integrator manager	2
	Contract manager	2
	Developer	2
	Stakeholder manager	1

5.3. Literature review

Inter-organizational collaboration (IOC) plays a critical role in the success of complex and interdisciplinary inter-organizational projects, especially in the construction industry (Kokkonen & Vaagaasar, 2018). This kind of collaboration can enable organizations to solve problems that they cannot tackle alone, and to achieve outcomes that benefit all parties involved (Butcher, Gilchrist, Phillimore, & Wanna, 2019). Moreover, collaboration can enhance flexibility, customer satisfaction, and service quality (Daugherty *et al*., 2006; Kumar & Banerjee, 2012; Whipple, Lynch, & Nyaga, 2010). Some of the main drivers for collaboration are the acquisition of different resources, the reduction of risk, and the application of diverse skills and knowledge (Borgatti & Foster, 2003; Kożuch & Sienkiewicz-Małyjurek, 2016; Phelps, Heidl, & Wadhwa, 2012; Satheesh, Verweij, van Meerkerk, Busscher, & Arts, 2022). However, collaboration faces

challenges, particularly in interconnected infrastructure projects, where multiple infrastructure owners have to coordinate their activities and interests. Interconnected infrastructure projects are those that involve the interconnection or intersection of different infrastructures, such as energy, water, transportation, and IT-based services (Grafius *et al*., 2020). These projects require a specific form of IOC that is characterized as "horizontal", meaning that there is no hierarchical relationship between the collaborating parties. This type of IOC has received limited attention in the literature, and there is a need for more empirical studies to understand how it can be assessed and improved. The objective of this section is to review the literature to extract the existing frameworks and criteria for assessing IOC in construction projects. This provides a foundation for a comprehensive and practical tool that can help practitioners to establish and maintain a collaborative environment in interconnected infrastructure projects.

5.3.1. Identified criteria based on the literature

Keast and Hampson (2007) assess multidisciplinary collaboration and identify four key relational management tasks: Activating, framing, mobilizing, and synthesizing. Activating refers to the selection of appropriate members and sufficient resources to enable collaboration. Framing refers to the rules, values and norms which emphasize working together rather than individually to overcome the complexity of the construction industry. Mobilizing is related to building a collective approach and shared goals, which leads to achieving not only the shared goals but also the goals of every single party. Synthesizing refers to maintaining relationships and establishing a collaborative culture rather than a competitive culture.

Keast and Hampson (2007) consider a competitive culture one of the main barriers in the construction industry which hinders synergy between different organizations. The relational management framework of Keast and Hampson (2007) focuses predominantly on the organizational aspect of collaboration, the

management, and governance of collaboration and largely ignores the softer aspects of collaboration such as trust.

Dietrich *et al*. (2010) developed a conceptual framework for multi-partner collaboration in construction projects and identified five criteria to assess its quality: communication, coordination, mutual support, aligned efforts, and cohesion. These criteria assess the relational dimension of IOC and focus on the contribution of the partners to the collaboration. However, organizational aspects such as the culture of the organizations, the importance of collaborative procedures, and the role of leadership are not considered in this list.

Keung and Shen (2013) identified key parameters to measure inter-organizational relationships within construction contexts. According to them, the assessment of inter-firm relationships is essential for practice in the field of construction. They propose a measurement model which includes five parameters: information exchange between project members, project communication system, knowledge sharing for collaboration, corporate culture for promoting networking, and learning capability in intra- and inter-organizational settings. Due to the fragmented nature of construction projects, information exchange and communication systems are the most important aspects to assess inter-organizational relationships (Keung and Shen, 2013). Keung and Shen positively embedded the learning capacity in their measurement model denoting collaborative openness and knowledge sharing and enriching collaboration in construction projects. Although communication and knowledge sharing are crucial to assess the status of collaborative relationships, broader organizational and individual collaboration aspects are required to be considered.

Suprapto (2016a) created a relational capability (RECAP) assessment tool to assess the status of relational aspects of collaboration during different phases of a project. The RECAP tool includes six main criteria: front-end definition, collaborative practices, relational attitudes, teamwork quality, project

performance and relationship continuity. Front-end definition is the ability to perceive the project goals and scope by the collaborative team. Collaborative practice refers to the integration of the collaborative team and jointly performing the processes. Relational attitudes are related to collaborative attitudes such as commitment, mutual trust, and no blame culture. Teamwork quality includes communication, coordination, balanced contribution, aligned effort, mutual support, cohesion, and trust. Relationship continuity refers to the willingness to continue the relationship in future. A long-term relationship indicates a satisfying collaborative relationship and successful prior collaborative project(s) (Pellicer, Sanz, Esmaeili, and Molenaar, 2016; Suprapto, 2016a). Suprapto also added a project performance criterion in his proposed tool, which assesses the efficiency (planning budget and schedule) and quality of a project. However, these aspects are outside the scope of the current study because the present study focuses on the collaborative relationship. Furthermore, it should be stressed that RECAP was developed to assess the collaboration between owner and contractor. The RECAP tool assists practitioners in being aware of the soft and relational aspects of collaboration over different phases of a project. However, this tool does not consider the learning capacity in collaboration assessment, which is an indication of sharing knowledge and openness among the collaborative parties (Liu, van Marrewijk, Houwing, and Hertogh, 2019).

The identified criteria to assess IOC based on the literature study are listed in Table 5.2, forming the basis for the conceptual assessment tool.

Individual collaborative capacity assesses the collaborative capacity among the members. The ability and attitude of involved members and their knowledge and expertise have a great influence on collaborative work (Foster-Fishman *et al*., 2001). The individual collaborative capacity includes three criteria: (i.1) attitudes and motivations, (i.2) attitudes about other project participants, and (i.3) ability to work with others. Attitudes and motivations refer to the commitment of collaborative members to contribute their specific knowledge and expertise

and to devote their own skills and knowledge to collaborative work. Contribution of resources, such as information and expertise, is an aspect of the quality of the collaborative work (Suprapto, 2016b), and the integration mechanism of a collaborative network (Keast and Hampson, 2007). Attitudes about other project participants represents the attitude of members in collaborating with other parties and includes two sub-criteria: having a collaborative culture rather than a competitive culture (Keast and Hampson, 2007) and personally trusting each other (Suprapto, 2016a). Ability to work with others refers to the ability of the involved parties to deal with conflicts during the collaborative project. The skilled members work constructively with the potential tensions and conflicts that lead to facilitating the collaboration.

Table 5.2. Assessment criteria based on selected literature (Conceptual assessment tool).

Category	Criteria	Sub-criteria	Literature			
			Keast and Hampson	Dietrich, Eskerod et al.	Keung and Shen	Suprapto, M.
Individual collaborative capacity (ICC)	Attitudes and motivations	Commitment to devote skills, knowledge, and resources	✓	✓		✓
	Attitudes about other project participants	Having a collaborative culture rather than a competitive culture	✓			
		Trust personally each other				✓
	Ability to work with others	Deal constructively with conflict	✓			
Relational collaborative capacity (RCC)	Working climate	Cohesion		✓		✓
		Involve the relevant members	✓			
		Stressing the benefit of working together	✓			
		Mutual trust between organizations				✓
		Support the champions of the collaborative project	✓			
		Supporting each other		✓		✓
		Existence of mutual flexibility		✓		
		Welcome new information and innovative ideas	✓			
	Shared vision	Mutual understanding of the goals, related activities, and interdependencies between the activities		✓		✓
		Establish a common vision and mission	✓			
		Have joint working processes				✓
		Alignment of contributions provided by collaborating actors with the expectations of the contributions		✓		✓
	Knowledge sharing	Encouraging the collection and dissemination of knowledge among members			✓	
		The willingness and ability to transfer explicit and tacit knowledge			✓	
		Gaining and applying new knowledge from the representatives of other organizations			✓	
	Relationship continuity	The level of engagement of the organizations in various steps of the project	✓			
		Continue the relationship in future				✓
	Value diversity	Understand and examine the perspectives of others	✓			
		Understand the cultural differences between organizations			✓	
Organizational collaborative capacity (OCC)	Leadership	Connecting the members to the network and driving the relationship to achieve outcomes by senior management	✓			
		Commitment of senior management to support the collaboration				✓
		Actively work of senior management together to resolve potential conflicts				✓
	Communication	Have a free flow of communication between all members	✓		✓	✓
		Have a system to facilitate high volumes of information sharing	✓	✓		
		The ability of collaborative actors to share their ideas openly		✓		✓
		The frequency of communication		✓	✓	
	Formalized procedures	Clear roles and responsibilities of team members	✓			✓
		Clear procedures and guidelines of processes in a collaborative work	✓			
		Clear values, norms, and rules	✓			✓
	Improved orientation	Monitor actions, needs and resources to meet common goals	✓			

The second category, **relational collaborative capacity** refers to the relationship between involved parties. The relational level is an important aspect of collaboration as IOC depends on the interaction of the involved parties. The relational collaborative capacity includes five main criteria: (r.1) Working climate, (r.2) Shared vision, (r.3) Knowledge sharing, (r.4) Relationship continuity, and (r.5) Value diversity. A working climate is one of the fostering

keys to a collaborative relationship (Foster-Fishman *et al*., 2001), including eight sub-criteria: cohesion, involvement of the relevant members, stressing the collaboration benefit, mutual trust, the champions and one another's support, mutual flexibility, and welcoming of new information and innovative ideas, warranted to create a positive collaborative environment. Cohesion stems from possessing a collaborative spirit and integration between parties from different organizations (Dietrich *et al*., 2010; Suprapto, 2016a), without which collaboration is impossible (Hoegl and Gemuenden, 2001). Selecting and involving relevant collaborative parties bring various resources and competencies together, and create synergistic interactions (Keast and Hampson, 2007; Powell, Koput, and Smith-Doerr, 1996). Stressing the benefit of working together convinces the parties that they can achieve more together than individually; without collaboration complex and interconnected projects cannot be realized (Keast and Hampson, 2007). Suprapto (2016a) identified mutual trust as a criterion to assess the relational attitude in collaboration, which is a relationship quality indicator not only between the members but also the involved organizations (Meng, 2012). According to Keast and Hampson (2007), in addition to a coordinator and director of a collaborative project as champions of collaborative projects fostering collaboration, who should be supported to bring the parties and ideas together, the involved parties should also support each other to attain common goals (Dietrich *et al*., 2010; Suprapto, 2016a). Moreover, effective collaborative projects warrant the ability of involved parties to adapt to unforeseen circumstances and changes (Dietrich *et al*., 2010). Being open and championing new information and innovative ideas are enabled by synergistic interactions which foster collaborative processes (Keast and Hampson, 2007).

Shared vision includes four sub-criteria: mutual understanding of the goals and related activities, establishing a common vision and mission, having joint working processes, and alignment of contributions of collaborating actors. Mutual understanding of goals and related activities leads to fluency in

interactions and prevents potential conflicts in collaboration (Dietrich *et al*., 2010). Furthermore, establishing a common vision and mission helps to unite the different parties with different perspectives and values under a collective whole and creates a sense of common ownership of the collaborative project (Keast and Hampson, 2007). In this regard, having joint working processes encourages the involved parties to make joint efforts for the collaborative tasks and improve the collaborative relationship in IOC (Suprapto, 2016b) and reduce adversarial relationships. Joint working can be any collaborative practice such as joint decision-making (Chan, Scott, and Chan, 2004; Suprapto, 2016a), joint problem-solving (Chan *et al*., 2004), jointly reviewing the plans, monitoring, reporting, and collaborative attempts for sustained improvement (Chan *et al*., 2004; Suprapto, 2016a). These efforts should also be aligned and meet the expectations of the involved parties to prevent disappointment and possible conflicts (Dietrich *et al*., 2010; Suprapto, 2016a).

According to Keung and Shen (2013), knowledge sharing is the activity that causes interaction among the members so the collection and distribution of knowledge should be encouraged. Sharing organizational knowledge leads to creating a learning capacity that enables involved parties to generate new ideas and innovative solutions. Sharing knowledge, willingness, and ability to gain and exploit knowledge in IOC leads to the improvement of relationships (Ekström, 2017) and facilitates IOC.

Engagement of the involved organizations and keeping them on board during the various steps of the project builds and maintains a collaborative relationship (Keung and Shen, 2013) which results in a successful collaborative project. According to Suprapto (2016b), a successful collaborative project increases the possibility of future relationships between different organizations. Collaboration between different organizations brings multiple perspectives, interests, and organizational cultures that should be understood by the involved parties. Respecting different cultures, perspectives, and investigating each other's

opinions create innovative solutions which enhance IOC (Keast and Hampson, 2007; Suprapto, 2016a).

The last category of the conceptual assessment tool is **organizational collaborative capacity** which consists of four main criteria: (o.1) leadership, (o.2) communication, (o.3) formalized procedures, and (o.4) improved orientation. Organizational capacity needs effective leaders with the ability to steer the collaborative members toward the outcomes (Keast and Hampson, 2007), skilled in resolving conflicts, and committed to supporting the collaboration (Suprapto, 2016a). In addition, developing a communication system, enabling the involved parties to access the information, and the abilities of collaborative parties to share their opinions openly with a high frequency of communication indicate effective communication to enhance the organizational capacity (Dietrich *et al*., 2010; Keast and Hampson, 2007; Keung and Shen, 2013; Suprapto, 2016a). Another proposed criterion for organizational capability based on the literature is establishing formalized procedures and structural arrangements through clarifying the roles and responsibilities, creating collaborative norms and values, and clear collaborative processes such as decision-making processes (Foster-Fishman *et al*., 2001; Keast and Hampson, 2007; Suprapto, 2016a). Finally, monitoring the progress of the collaborative actions to achieve the agreed common goals of a collaborative project (Keast and Hampson, 2007) sheds light on the required improvement points of IOC.

The reviewed literature highlights various aspects of inter-organizational collaboration in the construction industry. While each approach provides valuable insights, there is a consistent gap in adequately addressing the softer elements such as trust and learning capacity, which are pivotal for achieving successful and sustainable collaborations. Additionally, how to measure these in practice is not being addressed in any of them. Achieving effective collaboration in construction projects necessitates a balanced integration of the components, which can lead to improved outcomes and a more harmonious working

environment. This paper aims to develop a tool that allows to measure in practice collaboration and encompasses the full spectrum of collaborative elements to enhance the understanding and practice of horizontal collaboration in the construction industry.

5.4. Identified criteria based on the interviews

During the interviews, the practitioners alluded to multiple sub-criteria which, although being verbalized in different wording, still conformed to the criteria identified in the literature. Of the 34 sub-criteria identified in the literature, 30 were mentioned in the interviews. The four unmentioned sub-criteria are "supporting the champions", "aligning the contributions", "encouraging the knowledge collection", and "continuing the relationship in the future". The three most mentioned sub-criteria are "cohesion", "understanding and examining the perspective of others", and "clear roles and responsibilities of team members". According to the respondents, cohesion is a sign of the health of collaboration and of working together as a team. One of the project managers said that "*We are working together, and we speak with one mouth, and you could say we collaborate as one*". The manager believes that without team cohesion, collaboration will fail when faced with problems.

Collaborating with various organizations exposes the involved parties to different perspectives and ideas. According to the respondents, understanding and examining the perspectives of other parties indicates openness and respect among the parties. As such, a technical manager expressed that discussing the perspectives and giving feedback to each other, means that the team discusses the issues openly, takes each other seriously, and support exists among the team. One of the managers mentioned that "*by understanding the perspectives of others, you get to know each other better and you can understand the reasons behind the actions. It can prevent irritation among the team*".

As reported by the respondents, having clear roles and responsibilities among the collaborative parties indicates the existence of a clear structure in collaboration, and is an important criterion to assess the status of IOC. Clarity of roles and responsibilities facilitates referencing responsible roles for decision-making, particularly in unexpected events. A technical manager expressed that "*it is important to be clear who is responsible for what. It helps to decide efficiently. Clarity of roles and responsibilities can smoothen the decision process which is an indication of good collaboration*".

The respondents mentioned four criteria besides those identified in the literature to assess the status of IOC: willingness, achieving common goals, satisfaction of the parties with collaboration, and having no hidden agendas in collaboration. Willingness among the parties is a criterion mentioned by respondents to assess collaboration. One of the project managers argued that good collaboration among different parties depends on their energy, motivation, and willingness to collaborate. A technical manager supported this argument by stating that through this energy and willingness among the parties, collaboration runs at a high speed. A project manager also mentioned that "*if there is a willingness in a collaboration, that means they are trying to do the best for the collaborative work and they are eager to fix the possible problems among them*". According to the respondents, willingness to collaborate promises smooth problem-handling and realizing the best out of the collaborative work. It drives problem-solving and efficiently discussing potential conflicts among parties.

A good collaboration is the one in which the involved parties are satisfied. A project director stated that satisfaction with collaboration shows that the collaborators understand each other, respect each other's way of working and agree with the current collaborative work. According to an advisor, being unhappy with the collaboration flags issues in working together. The advisor mentioned that the collaboration could be assessed by asking the involved parties "*are we still happy with this collaboration? If not the relevant problems and*

issues should be identified and solved together". Hence, the satisfaction of the parties with the collaboration is taken up as an assessment criterion for IOC.

As collaboration is the quality of a relationship to achieve common goals among parties, the third suggested criterion is assessing the status of IOC based on common goals fulfilment. As reported by the respondents, achieving common goals shows that the collaboration is on track and expresses commitment and a good relationship.

Another criterion mentioned by respondents was transparency (no hidden agendas) among the involved parties from various organizations. As quoted by a respondent "*if there is no double agenda and we put the issues on the table, that means you are on the right track and a good atmosphere exists in a collaboration*". A project manager added that risk awareness is an important element of collaborative work which is a result of being transparent "*we should not have hidden agendas and inform each other on the predicted risks*". It helps to understand each other's risks and learn from each other to deal with the identified risks, which not only can prevent conflicts but also can build a good collaboration. Therefore, based on the interviews, transparency is an indication of trust and good relationships among parties.

To capture the practitioners' perspectives on the identified assessment criteria from the literature, they were asked to rank each criterion on a Likert scale (see Section 5.2.2). The results were analyzed and the statistical analysis of the ranking, including the minimum, maximum, mean, and standard deviation values are presented in Table 5.3. Figure 5.1 shows the frequency distribution of scores for each criterion and provides a visual representation of the level of agreement among the participants on the importance of each criterion.

Table 5.3. Descriptive statistics based on the respondents' ranking for each criterion.

Identified criteria	Minimum	Maximum	Mean	Std. Deviation
Attitudes and motivations	3	5	4.55	0.60
Attitudes about other participants	4	5	4.30	0.47
Ability to work with others	3	5	4.15	0.67
Working climate	3	5	4.25	0.64
Shared vision	2	5	4.10	0.97
Knowledge sharing	2	5	3.95	0.76
Relationship continuity	3	5	3.90	0.72
Value diversity	3	5	4.45	0.60
Leadership	4	5	4.80	0.41
Communication	3	5	4.20	0.83
Formalized procedures	2	5	3.55	0.83
Improved orientation	2	4	3.60	0.60
Valid N (listwise)	20			

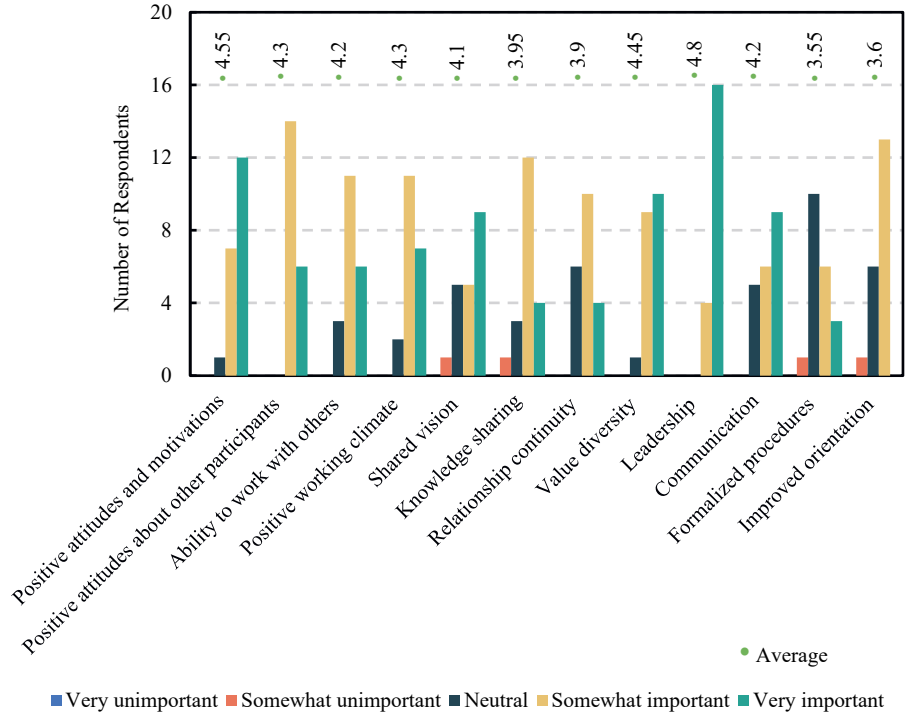

Figure 5.1. The practitioner's perspectives on the identified criteria from the literature.

Based on the mean value of each criterion shown in Table 5.3 and Figure 5.1, leadership, attitude and motivations, and value diversity are the most important criteria to assess IOC. Figure 5.1 provides insights into the level of agreement among the participants regarding the importance of criterion leadership. Sixteen out of twenty respondents consider leadership as "very important" criterion to assess IOC. As reported in Table 5.3, the standard deviation of criterion leadership (SD = 0.41) is the lowest value, showing relative consistency among the respondents. As quoted by a project manager and an advisor "*to know if everything goes right, if the people with the right capacity for collaboration are obtained, and if all noses are pointing in the same direction towards outcomes,*

leadership is an important criterion to assess". As reported by the respondents, leaders' support for collaboration and the collaborative team is an indication of a good relationship between leaders and the team, trust among them, the possibility to have good achievements, feeling safe to express different ideas and perspectives, and satisfaction of a team in collaboration. In this line of reasoning, another project manager mentioned that "*a collaborative team always looks at the leader how to act in a difficult situation, particularly in a crisis*". In this case, according to the results of the interviews, if the leaders are in contact and work together to solve the problems, collaboration can run beneficially, and all parties can be guided effectively through emerging problems.

Attitude and motivation with a mean value of 4.55 is the second important criterion to assess IOC. The standard deviation of this criterion, presented in Table 5.3, is relatively low but as shown in Figure 5.1, one of the respondents remains "Neutral" on the importance of criterion attitude and motivation. This respondent mentioned that "*attitude and motivation is an important criterion for any project performance. It is a general element and is not specific to assessing IOC, that is why I am Neutral*".

The respondents argue that IOC is not only about sharing specific knowledge and expertise, but also about having the motivation and willingness to collaborate and devote eagerness and energy to make the best out of collaborative work. An integration manager mentioned that "*if there is no positive attitude and motivation among the parties, you are pulling on a dead horse*". The respondents added that without commitment to share the required knowledge and resources, the collaboration can be hindered and fail to achieve the desired outcomes. Due to the complexities of infrastructure projects, the interrelatedness of designs, and the involvement of multiple actors, bringing specific knowledge, expertise and various resources together are indispensable to succeed in IOC.

Half of the respondents think that valuing diversity is also a "very important" criterion to assess IOC. Most conflicts find their roots in the existing different structures and cultures of collaborative organizational parties (van Marrewijk and Smits, 2016) which can cause misunderstanding among the parties engaged in IOC and hinder collaboration. Based on the results, understanding and appreciating the other parties' perspectives and the differences between various infrastructure organizations, not only prevents potential conflicts but also builds trust and respect in a collaboration.

According to Table 5.3, the criterion "formalized procedures" has a mean value of 3.55 and a standard deviation of 0.83. The results show that the respondents deem the criterion "formalized procedures" less important in comparison to other criteria. A relatively high value of standard deviation for the criterion "formalized procedures" indicates that the opinions of respondents on this criterion are partly dispersed. Figure 5.1 indicates that half of the respondents expressed a neutral opinion on the importance of criterion "formalized procedures", one respondent considered it "somewhat unimportant", and three respondents considered it as "very important". The respondents with neutral opinions believe that clear procedures are necessary and important during a collaboration, but these procedures are sometimes only documented on paper and not effectively implemented within the collaborative team. The respondent with a "somewhat unimportant" opinion advocated this argument and expressed that "*even though the clarity in procedures is important, the agreed norms and rules on collaboration mostly remain on the paper. The attitude and ability of team members to share ideas openly during a collaboration are more important criteria for assessment*". The respondents who view "formalized procedures" as a "very important" criterion for IOC assessment believe that for a collaboration between various organizations, clarifying the roles and responsibilities and establishing clear procedures for a

collaborative process can indicate order and structure to the collaboration. They argue that this can demonstrate the strength of the IOC.

Table 5.3 indicates that the criterion "shared vision" has a high value for standard deviation (SD = 0.97), indicating a considerable variation in respondents' opinions on this aspect. While nine respondents ranked shared vision as "very important" and five considered it "somewhat important" for assessing IOC, five of them remained neutral and one respondent viewed it as "somewhat unimportant". The respondents emphasized the importance of a shared vision as a criterion, believing that conflicts among collaborators often stem from a lack of shared vision and misunderstandings about collaborative project goals. A member of the steering committee mentioned that "*some conflicts happened during the collaboration, and it turned out after a while, that everybody interpreted the wording of the project goals and the requirements differently*". Assessing the IOC using a shared vision criterion can be beneficial, as the respondents pointed out that this criterion indicates that the collaborators are jointly working towards the same goals and there is a shared sense of purpose among them. However, one of the respondents argued that "*understanding the state and perspectives of the other organizations is more important than a shared vision in a collaboration*".

As explained in Section 5.2, further analysis has also been conducted by performing the Mann-Whitney test to investigate the difference between senior level and project team perspectives on identified assessment criteria. The significance level reported in Table 5.4 is higher than 0.05 for all criteria which suggests assuming the null hypothesis (existence of no difference) is true. Therefore, the results revealed no significant differences between the opinions of the two groups on the identified criteria. Furthermore, for each group, Table 5.4 displays the mean and standard deviation values of each criterion.

Table 5.4 also presents no significant differences between the two groups of respondents. The high standard deviations for the criterion of "shared vision" among the members of both groups indicate a greater variability in their opinions, as previously discussed. The mean value for criteria "knowledge sharing" and "relationship continuity" are slightly different among both groups. Based on Table 5.4, the senior-level group views "knowledge sharing" as a less important criterion compared to the project team group for the assessment "*if the required knowledge is not shared, you can find it yourself and proceed with a collaborative project. Therefore, this criterion may not be considered as highly important for assessment*". In contrast, the members of the project team group argue that "knowledge sharing" among various parties involved in a collaboration demonstrates openness and trust within the team, leading to enhanced synergy in the collaborative effort.

Table 5.4. Descriptive statistics for two groups of respondents on the identified criteria.

Function group		**Senior level (N = 9)**		**Project team (N = 11)**	
Identified criteria	Significance (Mann-Whitney test)	Mean	Standard deviation	Mean	Standard deviation
Attitudes and motivations	0.603	4.67	0.50	4.45	0.69
Attitudes about other participants	0.824	4.33	0.50	4.27	0.47
Ability to work with others	0.710	4.22	0.67	4.09	0.70
Working climate	0.766	4.33	0.50	4.18	0.75
Shared vision	0.710	4.00	1.00	4.18	0.98
Knowledge sharing	0.230	3.67	0.87	4.18	0.60
Relationship continuity	0.095	4.22	0.67	3.64	0.67
Value diversity	0.370	4.33	0.50	4.55	0.69
Leadership	0.552	4.89	0.33	4.73	0.47
Communication	0.656	4.33	0.71	4.09	0.94
Formalized procedures	0.552	3.67	0.71	3.45	0.93
Improved orientation	0.824	3.67	0.50	3.55	0.69

The mean value for the “relationship continuity” suggests that the senior-level group valued this criterion more than the project team group. The result of the Mann-Whitney test in Table 5.4, also indicates that the significance level ($p = 0.095$) for the criterion relationship continuity is on the edge. The senior-level group believes that being interested in maintaining a working relationship and potentially collaborating in the future indicates the satisfaction of the team during a collaboration. Conversely, some members of the project team group expressed a neutral opinion regarding this criterion, suggesting that while engagement with involved organizations is generally considered important

during a collaborative project, failure to involve them at every stage may not necessarily result in significant collaboration problems. In their view, the quality of the collaboration may be better measured by other criteria.

Based on the analysis of Table 5.3 and Table 5.4, it can be inferred that the identified criteria through literature are deemed to be practically important in the views of the respondents to assess the status of IOC in infrastructure projects. Furthermore, the respondents suggested the need for additional sub-criteria and minor modifications to develop an assessment tool, which are discussed in Section 5.5.

5.5. Assessment tool development

As explained in Section 5.4, the identified criteria from the literature were discussed with the infrastructure practitioners. Based on the feedback from them, two sub-criteria were modified to improve the structure and clarity. One sub-criterion was "stressing the benefit of working together". The results from the interviews show that every party should perceive the importance of collaboration "*it should be recognized by parties that they have to work together and need each other to achieve the goals and cannot do it alone. It shows that we try to realize not only our own goals but also the goals and interests of other parties, which also prevent potential friction among parties*". The results reveal that recognizing the benefit of working together indicates trust among parties to make together the best project outcomes and overcome problems during a collaboration. Therefore, the study outcome keenly offers that working together and the benefit of collaborating on a project should be recognized by a team and it should not necessarily be 'stressed' during collaborative work.

Another sub-criterion identified in the literature and further explored herein was to "support the champions of the collaborative project". Based on the results, all members of a collaborative project should be considered champions not only the coordinators of a project. Since the literature interprets a champion as a

coordinator of a project (Keast and Hampson, 2007), who should be supported during collaboration, the sub-criterion is accordingly modified to "supporting the coordinators of a collaborative project" to reflect the outcomes of the study.

The additional criteria are "willingness", "achieving common goals", "satisfaction of the parties with collaboration", and "having no hidden agendas" in collaboration. As stated by the respondents, "willingness" indicates the motivation and eagerness of the participants for joint efforts in a project. Therefore, according to the structure of the conceptual tool and the respondent's perspectives, willingness is added as a sub-criterion of attitude and motivation. They also consider "having no hidden agendas" as a sign of a good atmosphere in a collaboration. Therefore, this identified criterion is also added as a sub-criterion of working climate.

However, the other two mentioned criteria by respondents are mostly related to the results of collaboration and cannot be utilized as criteria to assess the status of collaboration in different phases of collaborative work based on the three categories mentioned. Therefore, these two criteria are used as control questions to assess collaboration.

By combining the identified assessment criteria through literature and the practitioner's perspectives, the proposed inter-organizational collaboration assessment tool (ICAT) is designed and developed, as shown in Table 5.5. The list of sub-criteria for the quantitative assessment of IOC in an infrastructure project can be found in the appendix B. Inter-organizational collaboration is assessed according to each sub-criterion based on a Likert-scale from (1: Strongly disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree, and 5: Strongly agree). Practitioners who participated in inter-organizational collaborations are requested to evaluate their collaboration by assigning scores to each sub-criterion using a Likert scale. The analysis of the assessment results conducted with the ICAT reveals the state of inter-organizational collaboration

within a project. Scores of 1 and 2 point to areas requiring improvement in collaboration, while scores of 4 and 5 underscore the strong aspects of the collaboration. In summary, the tool includes 12 criteria and 36 sub-criteria to assess the status of IOC in interconnected infrastructure projects.

Table 5.5. Inter-organizational collaboration assessment tool (ICAT).

(ICC). Individual Collaborative Capacity	i.1	Attitudes and motivations
	i.2	Attitudes about other participants
	i.3	Ability to work with others
(RCC). Relational Collaborative Capacity	r.1	Working climate
	r.2	Shared vision
	r.3	Knowledge sharing
	r.4	Relationship continuity
	r.5	Value diversity
(OCC). Organizational Collaborative Capacity	o.1	Leadership
	o.2	Communication
	o.3	Formalized procedures
	o.4	Improved orientation

The feasibility and usability of the proposed tool were discussed with practitioners during the interviews. Six of the respondents found the organizational collaborative capacity more feasible than the other categories to assess collaboration, arguing that there is more continuity at the organizational level, rendering it stable. Moreover, it is mostly based on documents and written aspects, therefore the routines in collaborative work can be tracked easily. In contrast, two of the respondents presumed organizational capacity as the hardest one to measure. They argued that these criteria are mostly related to the structure of different organizations and the results of them are accessible and measurable in the long term for a project, however, the individual capacity is the easiest one as quoted "*you can easily assess at the individual level if you can collaborate in*

a good way with your counterpart or not. But you cannot see the results at the organizational level on collaboration in a short period". Overall, most of the respondents believe that individual capacity is the hardest one to assess because it is more subjective and involves different personal opinions about collaborative work. The feasibility of assessing the relational category is between the two other categories. However, three of the respondents assumed relational capacity as a feasible one to measure. They argue that the relational capacity is assessable and observable over time and during different meetings.

The respondents assert the importance of assessing IOC using a tool. The respondents argue that "*the status of collaboration is partly discussed informally during meetings, but it would be beneficial to use a type of tool or a standard approach to assess collaboration*". It is essential to assess the status of collaboration between different organizations as quoted by a project director "*when collaboration does not go well, every project could become a disaster. So, if the collaboration is on the right track and the involved parties have a good match, then they can solve the most difficult project issues together*". The director also added that a project starts with people who have to collaborate because the results of a collaborative project are made by involved parties and if they do not collaborate well, the results of the project will go down. Therefore, an assessment tool assists the practitioners in evaluating the status of collaboration and recognizing the implicit points of a collaboration based on the identified criteria.

A project manager stated that sometimes there is an informal discussion about the collaborative work but not all points might be shared openly and discussed in a discussion which can increase the risk of collapsing a collaboration due to unawareness of the issues and unsolved issues, as quoted "*you are not always aware of what people do not share*". Therefore, it is helpful to use a tool to analyze the status of the collaboration. The results show that an assessment tool helps to obtain an insight into collaboration and awareness of the points that need

to be acted upon, "*if you do not assess, you cannot have a right image of the collaboration*". Based on the results of the interviews, it is not always required to take action to improve collaboration but at least try to understand the reasons behind the identified issues and adapt them. In this regard, a technical manager stated that "*the proposed tool has touched on the main subjects of collaboration, especially in a structured way. I could give a story for each of them. Then you can see the status and improve by strengthening each of these characteristics*". According to the respondents, the proposed tool assessed the relevant criteria, and it is not difficult to answer them. Moreover, the tool gives the possibility to openly discuss the status of the collaboration without revealing private information and to learn from the discussed issues.

5.6. Conclusions

As infrastructure projects become more complex and more interdependent, collaboration across various infrastructure organizations is essential. Infrastructure owners with different backgrounds, skills, cultures, and perspectives increasingly have to collaborate to realize a project. To facilitate such a collaboration, assessing the status of IOC and identifying the potential issues during collaboration are all critical steps. This chapter aims to identify IOC assessment criteria in infrastructure construction projects aiding to develop collaboration and design of an inter-organizational collaboration assessment tool (ICAT) to facilitate the collaboration process and its evaluation. The assessment tool was developed in two stages. The criteria from the literature were identified and classified into three categories: individual collaborative capacity, relational collaborative capacity, and organizational collaborative capacity.

In the second stage, in-depth interviews were performed to learn the practitioner's perspectives on assessing the status of collaboration between different infrastructure owners. Based on interviews, two sub-criteria from the literature were modified and four more criteria were identified to assess IOC.

However, only two criteria were added to the assessment tool as sub-criteria since the other two are outcome-oriented criteria and can only be used as control questions for the assessment of IOC.

The ICAT introduced in this study offers a valuable means to evaluate inter-organizational collaboration within collaborative projects. It serves as a foundation for practitioners to score and design collaboration (*ex-ante*) and assess the collaboration status during a collaborative project and in hindsight (*ex-post*), encompassing multiple dimensions and enabling the identification and analysis of underlying issues. Moreover, conducting follow-up interviews allows for a more in-depth analysis, facilitating active improvements in collaboration and providing decision-makers with targeted insights to enhance specific aspects of IOC. These interviews can include control questions to gather comprehensive opinions from involved practitioners and foster detailed discussions about their current collaboration in interconnected infrastructure projects.

The utilization of ICAT creates a robust platform for collaborative parties to engage in assessment discussions, fostering increased interaction, mutual understanding, and openness among practitioners involved in IOC. Regular assessments using ICAT actively contribute to enhancing the quality of collaboration and improving IOC outcomes.

From a scientific perspective, this research makes a significant contribution by identifying the key criteria for inter-organizational collaboration. The developed tool encompasses a total of 12 criteria and 36 sub-criteria, classified into three distinct categories. This comprehensive framework enables infrastructure owners to gain a clear understanding of IOC and evaluate collaboration status, identifying both strengths and weaknesses. By raising awareness of these identified points and collaboration issues, the tool empowers practitioners to comprehensively assess their current collaboration and take

targeted actions to enhance IOC in practice, addressing the root causes of identified issues.

Given the unique nature of each infrastructure project and its various phases, the relative importance of each criterion in the assessment process may vary. As a recommendation for further research, it would be beneficial to explore the impact and weighting of each criterion when assessing IOC, considering the size and specific circumstances of each project. Additionally, future studies could investigate the optimal frequency of using ICAT throughout a project's lifecycle, taking into account project characteristics. Furthermore, expanding the application of ICAT to a wider range of inter-organizational collaborations would provide valuable insights and further enhance its practical use.

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6

Facilitation Process of Inter-organizational Collaboration

The next generation of infrastructures is expected to be characterized by a higher degree of complexity and interconnectivity, driven by the need for advanced technology and the integration of various systems. To design and develop these infrastructures, a close collaboration between infrastructure owners is a necessity. By working together, infrastructure owners can leverage each other's resources, skills, and expertise and achieve synergies through the collaborative process. However, collaborating between various infrastructure owners can present challenges that impede seamless collaboration. This study aims to overcome the potential challenges and facilitate inter-organizational collaboration (IOC) during a project. To this end, the study proposes a participatory approach to facilitate inter-organizational collaboration in interconnected infrastructure projects. An action research method was employed in an interconnected infrastructure project in The Netherlands to develop a process for daily practice. The IOC facilitation process (IOCF) developed in the study comprises several stages. Each stage includes four general steps: data gathering, data analysis, feedback, and iterative enhancement cycles. The suggested process benefits the infrastructure practitioners in resolving collaboration issues through iterative cycles and assessing the overall collaboration status, with the goal of gradually facilitating the collaboration processes in interconnected infrastructure projects.

6.1. Research methodology

Design and development of interconnected infrastructures with strong interdependencies between various infrastructures is a complex task and requires multi-disciplinary knowledge and skills, complementary resources, and exploiting various experts' perspectives. Assembling the required expertise and knowledge within a single organization for the execution of a design and development infrastructure project is challenging, if not impractical. Therefore, collaboration between various infrastructure owners, known as inter-organizational collaboration (IOC) is considered beneficial for the design of next-generation infrastructures (Nezami, de Bruijne, Hertogh, & Bakker, 2022a). However, research into interconnected infrastructure projects indicates that the way infrastructure operators approach infrastructure projects often falls short of genuine collaboration (Nezami *et al*., 2022a). Further studies are needed to support the implementation of effective IOC between infrastructure owners and its process during such projects.

In previous chapters, the current status and the potential issues of IOC in interconnected infrastructure projects were investigated. Furthermore, the underlying building blocks (*i.e.,* factors) of an inter-organizational collaborative project organization were discovered. An assessment tool was developed to identify issues that hamper collaboration (Nezami, de Bruijne, Hertogh, & Bakker, 2024). However, establishing a collaborative project team is a challenge which requires ongoing efforts to manage and develop collaborative processes. To support the development of IOC in project teams, the implementation of a participatory approach to stimulate inter-organizational collaboration in interconnected infrastructure projects is discussed in this chapter.

IOC follows the efforts of involved individuals in a collaborative project to develop innovative solutions and create synergy (Emmitt & Ruikar, 2013), and this requires ongoing efforts of all involved parties to facilitate collaborative

processes (Raišienė *et al*., 2015). To study and contribute actively to this process, action research can be a promising approach. The importance of action research cannot be overstated in mobilizing and engaging practitioners in each step to actively pursue collaboration via processes and tasks (Huzzard, Ahlberg, & Ekman, 2010). Unlike conventional research approaches, action research adequately fits the requirements for a method to develop and study management practices in dynamic systems (Perry & Zuber-Skerritt, 1992).

6.1.1. Action research

The knowledge developed in the previous chapters creates a solid foundation to study collaboration in interconnected infrastructure projects. The sponsor of the research, the network "Next-Generation Infrastructures" is interested in the possible impact of the present research on the daily practice of projects for the asset managers that are partners of the network. Considering this motivation, this chapter aims at bridging the scientific and the practical perspectives to explore possible solutions in close contact with the practitioners to facilitate inter-organizational collaboration.

Action research is a valuable approach for collaborative projects as it allows for the active involvement of all parties in the research process (Svensson de Jong, 2021). This approach emphasizes the importance of continual reflection and adaptation, leading to a more dynamic and responsive project (Richter, 2016; Svensson de Jong, 2021). Action research can lead to more relevant and practical findings by actively involving practitioners in the research process, ultimately leading to more effective solutions (Bilandzic & Venable, 2011; Huzzard *et al*., 2010) for the identified issues related to the subject matter. Hence, applying action research to the context of the present study holds promise for finding and implementing effective solutions to address IOC issues, thereby contributing to the facilitation of IOC.

In contrast to traditional research, where the researcher is a passive observer and often separated from the system under investigation, in action research the researcher takes an active role in the process of investigation of complex and dynamic topics which include people's interaction with their socio-cultural environment (Connaughton & Weller, 2013; Greenwood & Levin, 2007; Perry & Zuber-Skerritt, 1992). Besides increasing the involvement of both the researchers and practitioners, action research enhances knowledge generation about actions and interventions in collaborative projects (Coghlan, 2007). However, the main goal of action research is to produce actionable, practical knowledge to guide organizational development (Coghlan, 2007; Zuber-Skerritt & Fletcher, 2007). According to Zuber-Skerritt and Fletcher (2007), action research can be an effective approach to study horizontal collaborations where the collaborative parties are in a relationship in which equality is assured to make joint decisions and learn from the results of those decisions that can enhance their collaboration.

The focus of the present chapter is on developing a process to facilitate IOC in interconnected infrastructure projects in The Netherlands based on what has been learnt in the previous chapters. In Section 6.2 the process of action research and the case under investigation are discussed. Performing action research in an interconnected infrastructure project is described in Section 6.3, and its findings and discussion are presented in Section 6.4. Section 6.5 presents the conclusions of this study as well as recommendations.

6.2. Methodology

Action research can be described as a practice-based approach to generate scientific knowledge through collaboration between researchers and practitioners (Bradbury-Huang, 2010; McNiff, 2016) that integrates pre-existing organizational knowledge with applied behavioral science knowledge to solve organizational issues (Coghlan, 2007; Shani & Pasmore, 1982). According to

Coghlan (2007) and Shani and Pasmore (1982), action research is conducted in a collaborative and co-inquiry spirit between researchers and practitioners and focuses on working "*with*" rather than "*for*" practitioners (Greenwood & Levin, 2007).

Action research combines three elements: action, research, and participation; in case any of the elements is missing, the process is not action research (Greenwood & Levin, 2007). The action element is about improving practice, the research element generates knowledge about this practice (McNiff, 2016). The participatory element explicitly involves practitioners in problem-solving (Connaughton & Weller, 2013; Coughlan & Coghlan, 2002; Huzzard *et al*., 2010). The participatory approach increases acceptance of change in an organization (Coughlan & Coghlan, 2002), raises participant motivation and draws on the knowledge of all participants (Cap *et al*., 2019).

Kurt Lewin, widely regarded as one of the pioneers of action research, described its process as "a spiral of steps", that includes planning, action, and fact-finding about the action's outcome, which eventually leads to organizational change (Lewin, 1946) with a continuous, iterative sequence of activities (Baskerville, 1999; Connaughton & Weller, 2013; Kemmis, McTaggart & Nixon, 2013). Connaughton and Weller (2013) adopt Lewin's model and suggest the cyclical process consists of diagnosis, action-planning, action-taking, observing, reflecting, and re-diagnosis to following cycles which is also similar to the process suggested by Battistella, De Toni, and Pillon (2015). McNiff (2017) presents an action-reflective cycle that consists of observing, reflecting, acting, evaluating, and modifying processes. Cap *et al*. (2019) applied an action research method to manage an inter-organizational network and proposed the action research cycle by developing the process presented by Battistella *et al*. (2015) and Coughlan and Coghlan (2002) because of its broad literature grounding, its wide utilization, and its practical utility (Cap *et al*., 2019). This approach is also adopted in this study. To conduct an informed data feedback

session and discuss feasible actions to implement with practitioners, the data analysis step is performed before the data feedback step. Hence, the steps adopted in this research to improve IOC in interconnected infrastructure projects include defining purpose, data gathering, data analysis, data feedback, action planning, implementation, and evaluation (Coughlan & Coghlan, 2002).

6.2.1. The steps of action research

In the first step, the context and purpose of the research are defined. Understanding the conditions and framing the research goal is necessary to initiate the collaboration of the researcher and the practitioners (Coughlan & Coghlan, 2002; Schruijer, 2006). Data about the context of the research is collected in the second step, which is an important aspect of action research (Schruijer, 2006) and requires the active involvement of the researcher in organizational processes (Coughlan & Coghlan, 2002). Data can be collected through interviews, surveys, experiments, informal contacts, and observations (Cap *et al*., 2019; Coughlan & Coghlan, 2002; Dickens & Watkins, 1999; Schruijer, 2006). The third step is data analysis. The data that is collected in step two is subsequently interpreted and analyzed in collaboration with practitioners.

The results of the data analysis, including results of observations, interviews and assessments are presented and fed back to the practitioners in the organization in the fourth step, which is called data feedback (Dickens & Watkins, 1999). The researcher, in collaboration with practitioners, can identify a need for change and the potential direction of change. The feedback can be given in a feedback session, providing an opportunity to discuss the issues (*i.e.,* a problem or matter that requires attention or action), possible directions for improvements, and to take further actions with practitioners (Connaughton & Weller, 2013). Additionally, the feedback session can include discussing participants' perspectives on events and reflecting on the experience from

previous steps or improvement cycles (Connaughton & Weller, 2013; Huzzard *et al*., 2010).

Based on the analyzed data and the discussions in the feedback session, possible actions are planned in the fifth step: "action planning". Action planning is a joint activity in which the practitioners discuss and ideally decide on the issues that need to be changed or improved in an organization (Cap *et al*., 2019; Coughlan & Coghlan, 2002). Implementing the planned action is the next step that involves all participants. The desired changes and improvements require the active involvement of and taking action by the participants (Coughlan & Coghlan, 2002).

The evaluation step reflects, and reviews implemented actions that have been taken (Cap *et al*., 2019; Coughlan & Coghlan, 2002). Evaluation prevents the propagation of errors and ineffectiveness of the actions and is essential for learning (Coughlan & Coghlan, 2002; McNiff, 2017). The evaluation also contributes to a more successful iteration in the next cycle of action research and future enhancements (Cap *et al*., 2019; Schruijer, 2006).

6.2.2. A case of inter-organizational collaboration

A case of an interconnected infrastructure project was chosen to perform action research to facilitate IOC. The case is a horizontal collaboration between two infrastructure owners to develop a public transport hub in The Netherlands. The project aims to enhance the capacity, safety, and quality of the transport hub. The interfaces between the infrastructures necessitate close collaboration between two infrastructure owners to realize the project. The collaborative project is studied in the early stage of the project (pre-design phase) and is managed by different levels, which are shown in Figure 6.1.

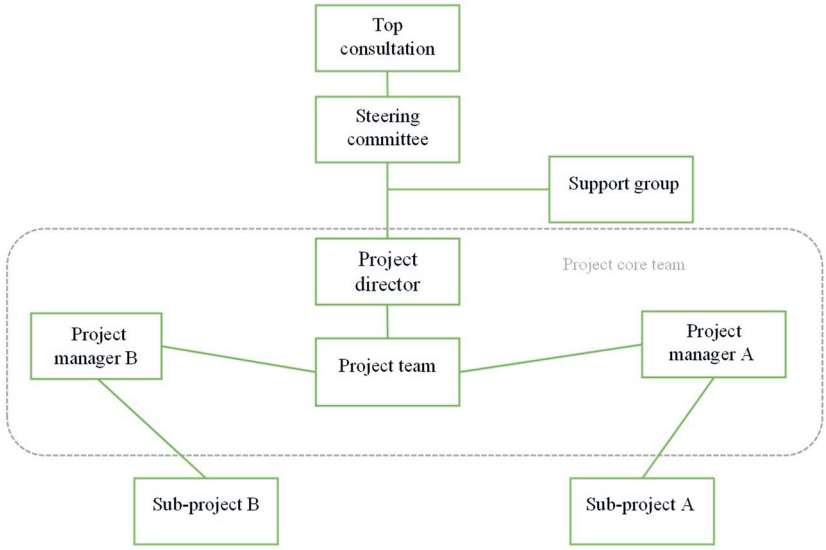

Figure 6.1. The organizational chart of the collaborative project.

According to Figure 6.1, each sub-project team works with its own project manager and reports the progress to the project director. The project core team is where possible collaboration occurs and consists of the project managers of two infrastructure organizations, a project director, a risk manager, a project control manager, stakeholder managers, and technology managers. The support group receives the reports and initial project decisions from the project core team and reflects on them and guides the project team before sending the reports and documents to the steering committee. The steering committee members discuss internally and mutually make decisions on the issues submitted by the project team. The potential unsolved conflicts also escalate to the steering committee. If the required decisions are not made or conflicts are not solved the process escalates to the top for resolution.

The researcher participates in the project core team to perform action research for approximately one and a half year. The project core team holds weekly team meetings to manage the project. The researcher observes and collects data

through the core team and takes on the role of advisor of collaboration towards the team. The steps and the processes of performing action research to facilitate IOC in the case are described in Section 6.3.

6.3. Implementing action research

This section provides an overview of the action research method employed in this study to facilitate inter-organizational collaboration (IOC) in an interconnected infrastructure project.

The action research process was initiated with the aligning of the research objectives of this thesis with the goals of the project team. In other words, from the start, the research set out to contribute practical value for practitioners while at the same time setting out to develop a method to measure as well as improve inter-organizational collaboration. The researcher presented the research aims to the project director and management team members to secure their support. A project start-up meeting with the core project team followed, where the collaboration agreement was established, and the researcher's role to the project was clarified as facilitating collaboration between the two infrastructure organizations.

Data collection for the action research occurred in three stages in the period 2019-2022. The first stage lasted approximately eight and a half months and involved baseline data collection to understand the status of inter-organizational collaboration (IOC) and learn to understand about the infrastructure project without any intervention. Subsequent stages focused on helping and stimulating the project team to invest in the assessment of collaboration and the activation of their willingness to contribute to an improvement in their collaboration. As part of this stage the focus of the research lay with the development of the process that was designed to help the team discuss and select which aspects they wanted to improve. These included the development of a number of project team meetings, which were held to discuss these issues in depth. Simultaneously, from

a more scientific perspective, the research focused on the development of a method to assess the impact of the implemented actions to improve collaboration. During this phase the research process was affected by the COVID-19 pandemic, which caused considerable delays and limited the number of improvement cycles that could be initiated during the action process phase of the research to three.

The data gathering methods employed during these phases involved observations (meetings, exchanges between practitioners, reading project documentation etc.), informal contacts with practitioners (*i.e.* (online) talks over coffee or in the margins of other meetings), and the employment of the inter-organizational collaboration assessment tool (ICAT) described in Chapter 5. Observations of participant actions and collaboration dynamics were recorded in a logbook, while ICAT assessments and follow-up interviews provided the bulk of the information which resulted in overviews of the IOC's strengths and weaknesses. These overviews were shared during the improvement cycle with the project members. In this way, commitment was sought, and organizational members could learn and reflect on the topic of IOC improvement.

Quantitative data from ICAT were analyzed and presented to the core team, with qualitative insights from interviews enhancing the understanding of collaboration challenges. This analysis concluded in feedback sessions where findings were discussed, followed by workshops to brainstorm solutions for identified issues. Actions were selected for implementation based on these discussions.

The findings from this action research and the challenges encountered during the implementation of action research for IOC facilitation are detailed in Section 6.4.

6.4. Results and discussion

6.4.1. Facilitation process

A fundamental assumption in action research is that one can focus on a specific element, aiming to improve it continuously through iterative cycles (Coughlan & Coghlan, 2002). However, this approach turned out to be less practical in inter-organizational collaborative projects due to their dynamic nature. During the project when the researcher was involved, various issues emerged, and collaborators' priorities frequently changed as a consequence of these events. For example, due to the outbreak of COVID-19 one of the organizations was forced into a reorganization that significantly affected the project team. Some employees initially assigned to the project thus were 'taken' from the project. Furthermore, the project turned out to be composed of a multitude of interconnected problems that required immediate attention, making it difficult for the project team to maintain a narrow focus on a single issue. Consequently, the conventional action research methodology, which emphasizes isolating and resolving one problem per cycle, may not be sufficient in more complex, dynamic, and evolving collaborative environments. As collaborators involved in these projects encounter a multitude of interconnected problems, any suggestion of focus and a call of addressing these issues in isolation did not lead to comprehensive or sustainable solutions and this reduced their motivation and commitment as well as challenged the value of the research project. Hence, a more flexible approach is needed to address the complexities and interdependencies of multiple issues.

Given that IOC is multidimensional and influenced by a variety of factors, it is important to acknowledge that the impacts of actions are difficult to identify in isolation; instead, they are usually frequently intertwined with other activities that take place simultaneously. This complexity necessitates the development of precise and focused evaluations to understand the efficacy of any implemented

action and its overall influence on IOC. Recognizing these challenges, this study adopted an alternative approach to evaluate collaboration at both the issue level and the broader collaboration level. This structured approach allowed for iterative cycles of action planning, implementation, and evaluation, although COVID-19 disruptions necessitated adaptations, including a team-building session to re-establish a collaboration-oriented focus among project team members. While further ICAT assessments were planned, COVID-19 led to significant organizational changes, hindering collaboration, and delaying the facilitation process cycle. Despite these challenges, the research continued, with stages two and three focusing on addressing evolving collaboration issues through iterative action cycles.

This modified approach to facilitate IOC involves conducting formative evaluations at the issue level, where specific challenges are addressed as they arise, and assessing the overall impact of these actions on inter-organizational collaboration in a summative manner. By combining these evaluations, the study provides a more comprehensive understanding of the collaboration's status and contributes to its facilitation. By adopting this dual evaluation method, practitioners are expected to be better equipped to navigate the dynamic and unpredictable nature of collaborative projects. This approach allows practitioners to address issues that occur in their daily practice and connect these to IOC, while still maintaining a focus on the overall effectiveness of the IOC. The flexibility and responsiveness embedded in this approach ensure that collaboration can be presented as a "robust" topic. This means that collaboration is an ongoing topic with high importance throughout the project that requires continuous monitoring and needs to be adaptive even if the project moves along or faces significant changes.

Regular events to raise awareness and focus on identification and prioritization of collaboration issues turned out to be essential for developing a viable IOC facilitation process. Regular assessments using the ICAT enable

infrastructure practitioners to stay informed about the status of the collaboration and its associated issues. To maximize the effectiveness of the facilitation process, it is recommended to begin each project stage with an assessment using the ICAT. This initial evaluation helps to establish a baseline for the collaboration at the stage level. However, in the early stages of a project, team members may have limited familiarity with one another and underdeveloped relationships, as the collaborative project has only just begun. Therefore, for the first stage, it is advisable to conduct the ICAT assessment after the team's formation phase, when the foundation of the collaborative team and interpersonal relationships have been established (Savelsbergh & Storm, 2014).

To address the complexities of IOC in a dynamic environment, the IOC facilitation process (IOCF), as shown in Figure 6.2, was adapted in this study. According to Figure 6.2, each stage of the IOCF process comprises four generic steps: data gathering (DG), data analysis (DA), feedback (FB), and iterative enhancement cycles (EC) to address identified issues. The first three steps are focused specifically on evaluating and improving collaboration at the stage level. The iterative enhancement cycles then seek to address the prioritized issues/topics of the IOC through a structured process involving planning and action, observation, and reflection. The feedback generated in the FB step informs the subsequent enhancement cycles. This approach allows for a dual evaluation: the effects of implemented actions are assessed both at the issue level through reflections in the enhancement cycles and at the broader collaboration level using the ICAT.

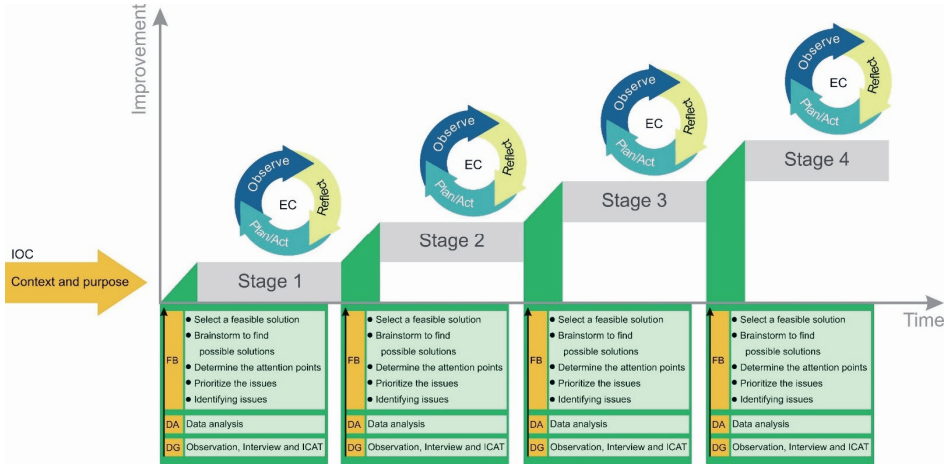

Figure 6.2. The IOC facilitation process (IOCF) developed in the present work. Depending on the complexity of the project, multiple enhancement cycles (EC) can be defined in a single stage. Additionally, these cycles may be repeated multiple times during a stage.

Data gathering is performed through observation, interviews and assessment using the ICAT, and the collected data are analyzed to assess the collaboration status and identify potential issues. Issues to concentrate on during each stage are prioritized by the project team based on the situation and the team requirements using the Eisenhower matrix technique (Baker, 2019; Zhu, Yang, & Hsee, 2018) and the attention points are determined. Brainstorming sessions are organized to discuss potential feasible solutions/actions and the time required to implement those actions. The action planning is performed and implemented to work on the prioritized issues, as discussed in Section 6.3, aiming to improve IOC through enhancement cycles. It should be noted that based on the type of issues and the planned actions, a few cycles can be simultaneously conducted to address different issues in a single stage. The outcomes of the implemented actions are then observed during the collaboration process. Based on the reflections made by the researcher and the project team, the effects of the implemented actions are discussed. In case the actions do not realize the desired effect on the specific issue and, from a broad perspective, on the collaboration,

the cycle reiterates with some modifications or with a new action decided upon by the project team. After attaining the desired outcomes from an enhancement cycle on a specific issue, the team can proceed with continuing to work on the same issue for further improvement or define another cycle to work on the next issue on the prioritized issue list. It is worth noting that the number of cycles needed to reach the desired outcome is not necessarily the same for all the issues; hence, working around a specific issue may require more (or less) time than working on others.

Changes during IOC are unavoidable due to the intrinsic dynamics of collaborative projects; thus, regular assessments are needed to obtain a clear picture of the status of collaboration and its relevant issues. The list of identified issues and their priorities are updated after each stage. If an issue remains unresolved, the list of issues may include issues from a previous stage. The number and duration of stages depend on the project schedule, the type of identified issues, the process of the enhancement cycle, and the requirements of the infrastructure collaborators. Executing short-duration stages may be insufficient to really notice the effects. Conversely, executing long-duration stages can lead to overlooking important collaboration issues, project team needs, and the impact of possible changes during collaboration. As a recommendation, reiterating the facilitation process stages every quarter of the total project time could be a reasonable choice for a year-long project to cover important issues that emerge during a collaborative project. This recommendation is based upon the researcher's intuitive insight and concurs with the quarterly reports of the project team as presented to the upper level of management.

6.4.2. ICAT assessment results and attention points discussion

The assessment tool utilized in the project features twelve criteria and 36 sub-criteria, as outlined in Chapter 5. The project team was asked to evaluate each

sub-criterion using a Likert scale, with scores ranging from 1 (strongly disagree) to 5 (strongly agree). Results with scores 1 and 2 indicate areas for improvement in collaboration, while scores 4 and 5 highlight the strengths of the collaboration. The researcher conducted follow-up interviews with the team to gather further insight into the scores and determine the underlying reasons for the scores. The results of the assessment tool and the reasons identified in the interviews were then presented during a feedback session, in which the status of IOC was discussed and evaluated.

The results obtained from the ICAT using two rounds of assessment and the status of collaboration are presented in Table 6.1 and Figure 6.3.

The second-round assessment using the ICAT reveals that the facilitation process has led to a general improvement in inter-organizational collaboration, as demonstrated in Table 6.1. The most notable improvements are seen in the areas of "shared vision" and "communication".

Table 6.1. The results obtained from the ICAT. Averaged scores are reported here.

Criteria			First ICAT		Second ICAT	
(I). Individual Collaborative Capacity	i.1	Attitudes and motivations	4.3	3.9	4.2	3.7
	i.2	Attitudes about other participants	4.0		3.4	
	i.3	Ability to work with others	3.4		3.6	
(R). Relational Collaborative Capacity	r.1	Working climate	3.5	3.4	3.6	3.7
	r.2	Shared vision	3.2		3.6	
	r.3	Knowledge sharing	3.6		3.9	
	r.4	Relationship continuity	3.5		3.7	
	r.5	Value diversity	3.2		3.5	
(O). Organizational Collaborative Capacity	o.1	Leadership	3.1	3.3	2.6	3.4
	o.2	Communication	3.7		4.1	
	o.3	Formalized procedures	3.5		3.6	
	o.4	Improved orientation	2.9		3.1	

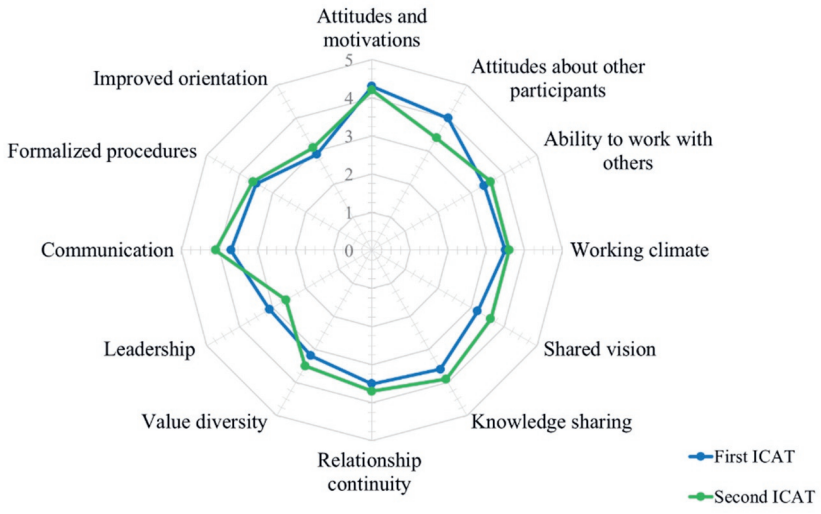

Figure 6.3. The status of the inter-organizational collaboration.

The results show that the average score for the criterion "shared vision" has increased from 3.2 to 3.6, which is mainly attributed to the action implemented to create joint working processes between the project core team. The identified issue under this criterion was the lack of joint collaboration and the requirement to establish an integrated design for the project. The project encompasses different sub-projects that each organization worked on independently and reported to the other organization in a project team.

However, it was clearly not a joint working process for a collaborative project. One of the members mentioned, "*it is an integral project, and we should work on that together. During the design of the project, there is no linking pin between the sub-project teams*". Another member explained that "*our project manager is part of the team and shares high-level information and the overall progress of the design. In this way, we miss the detailed information we need to proceed with the design and development processes. Sometimes we got a proposal about the plan or design from sub-project team A that we should react*

to or confirm it based on our requirements. We don't have a good feeling because we are not involved in the process. We should find a way to be involved more early in the process".

It should be noted that what is happening at each sub-project might have a huge influence on other parts of the project. Because of the lack of a linking pin between them, the opportunities for synergistic collaboration are significantly reduced. This contradicts the principle of collaboration that emphasizes early involvement in the design phase rather than seeking input only after progressing in the design and reporting back for confirmation. This issue was reflected in the feedback session and a collective solution was to establish a "coordination and integration meeting" where the developers, design teams, and technical managers were involved to discuss the design process together and exchange ideas for the design.

The joint working process and sharing of ideas, knowledge, and experience not only led to a synergistic collaboration but also supported finding the best possible solutions and design for the project. This meeting was organized every two weeks between the relevant participants. The enhancement cycles (according to Figure 6.2) were iterated by modifying the agenda and program of the meetings based on the needs of the participants to improve this action. The reflections of the participants were positive about this action, as participants expressed that "*it works quite well, there were a lot of impactful discussions, particularly on the technical level during the meeting. We learned a lot from each other during the process*"; "*we shared more information on the developments and discussed both sides' requirements that lead to a concrete plan*".

According to the project team reflection, implementing the action "coordination and integration meeting" had a positive impact on knowledge sharing and collaborative learning during IOC, which was reflected in ICAT

regarding the criterion “knowledge sharing”. The average score of the criterion rose from 3.6 to 3.9 during one of the improvement cycles (see Table 6.1). Additionally, alleviation of the COVID-19 restriction enabled the project team and research to implement “co-location” as a suggested action. The aim of the action is to enhance joint working processes and improve communication among the core project team, thus contributing to IOC. By designating a specific day of a week as “project day” and inviting key participants to work together at one of the organizations, the team opted to foster informal communication, build stronger relationships, and collaborate more effectively. Both factors turned out to be crucial for facilitating the achievement of IOC as discussed in Chapter 4.

The results of the ICAT after implementing these actions indicated that the contributions of the (sub) project team were aligned (as reflected in the ICAT results for the sub-criterion, which improved in score from 3.1 to 3.8) and there was an improvement in the evaluation of joint working processes (reflected in the ICAT, which showed an improved score from 3.1 to 4.1). Both were sub-criteria of a shared vision. The improvement was also reflected in the criteria relationship continuity (from 3.5 to 3.7) and communication (from 3.7 to 4.1) as shown in Table 6.1.

The other point of improvement is in the area of “communication”. The data gathering (DG) step at the IOC level revealed that there were difficulties with the sharing and accessibility of data between the sub-project teams from the two organizations which form sub-criteria of the “communication” criterion in the ICAT. Each organization uses its own internal database with restricted accessibility. However, establishing a common data platform, which contains the project-required documents (*e.g.,* memos, meetings minutes, design documents, *etc.*), accessible to all participants, was deemed necessary to facilitate IOC (Nezami *et al*., 2022a), and mentioned as a solution in the brainstorming session.

The implementation of the action started with organizing a workshop to teach the team how to use the platform. Such a workshop was needed because the new system differs from internal platforms employed in the parent organizations and the team members were reluctant to learn a new system. Focusing on this issue, from observing the behavior and the process of using the platform, it was understood that a few iterations of the enhancement cycle are needed to address the issue by organizing a workshop to discuss the team's requirements for further development of the platform, which had positive reflections from the project team. Another iterative action cycle for this issue was to create a standard and common format for the documents uploaded by each team member, which facilitates easy and fast retrieval of documents. One of the members mentioned, "*we also use the platform for reviews of design and tender documents together, and I'm glad because it's traceable, and that we can work on the documents together*".

Via regular platform use, potential improvement points can be identified and solved through iterating the enhancement cycles. Utilizing a common platform enables the participants to work jointly on documents and track changes during the project. A common data platform also enhances communication by providing a tool to overcome information asymmetry among the project team. As such, it facilitates the sharing of information (Keast & Hampson, 2007) as indicated by the results of the ICAT assessment.

Another action that has an impact on "communication" was the action implemented for improving the issue related to the lack of clarity about roles and responsibilities. This was another issue that was identified from the results of the first round of assessments using the ICAT. The observations also indicated that there was confusion in terms of "who is responsible for what" or "this task belongs to which role/person" which is sometimes an issue in this type of collaboration. There were two points for ambiguity in the roles and responsibilities. The first one is that certain people had double or multiple roles

in the project and the other point is that there are some differences in the definition of the roles between different organizations. This issue and the possible solutions were discussed in the feedback session and among them, it was decided to create a "Facebook" and implement a "soapbox" session. The Facebook is a document in which each participant explains their role, responsibilities, and related tasks in the project which is shared with the whole team. A soapbox session is an informal meeting held every two weeks, during which one or two participants give presentations using the suggested format and talk about their roles, responsibilities, tasks they are performing and their plans. Performing this session also helped the team to be aware of each other's tasks and find opportunities to collaborate. As reflected by the project team, this action also fosters the open sharing of ideas and knowledge within the project team, enhancing communication during the IOC. Modifications were made to implement in the next enhancement cycle based on the team's requirements. Challenges or specific issues that each participant faced as each performed their tasks were also discussed in a "free-format session" and defined as a new action, creating opportunities for synergistic collaboration through exchanging ideas and acquiring new knowledge to achieve the best possible (or innovative) solutions for that challenge.

Despite the general improvement in the IOC, the action taken to enhance the team's cohesion has not effectively resolved the issue at hand. The team was attempting to blur their organizational boundaries, however, the issue in the high-level management propagated to the team and hindered integration between the project core team. This issue also did not have a positive effect on the criterion "attitude about other participants", reducing its average score from 4 to 3.4, as shown in Table 6.1. The sub-criteria of the criterion "attitude about other participants" are trust and collaborative culture of the team members, as explained in Chapter 5. One of the team members expressed that "*after arising of the conflict of interest among the steering committee, it seems that project*

manager B seeks and protects the interests of their own organization and values their own organizational perspectives more than the interests of the collaborative project". According to the team members, conflicts arising in the high-level management regarding a specific part of the project lead to pursuing the parent organizational interests instead of the collaborative project interests, spreading the feeling of distrust and a competitive attitude among the team as reflected in the results of the ICAT.

The conflicts of interest in the high-level management resulted in less trust in the leadership and adversely impacted the support they provided to the team. Table 6.1 shows that the average score for the criterion "leadership" has decreased from 3.1 to 2.6. The collected data revealed that the project team expects the high-level management to support the collaboration by aligning their interests together, solving the conflicts collaboratively and enhancing the decision-making processes. Analysis of the collected data suggests that discrepancies exist in the level of detail between the information communicated among the project team and high-level management. It was determined that there are instances where the steering committee's decisions are not effectively communicated to the project team. The lack of documentation on the reasoning behind decisions or assignments can result in difficulties and potential rework. However, to support informed decision-making, it is also essential for high-level management to receive sufficient information. To address this challenge in the decision-making process, it was necessary to explore solutions to improve communication between the project team and high-level management. Unfortunately, due to time constraints, this aspect was not addressed in this research.

Despite the aforementioned issues, the results obtained from the ICAT, as shown in Table 6.1 and Figure 6.3, and feedback from the project team suggest that the implementation of the IOCF process, as depicted in Figure 6.2, led to an enhancement in collaboration across various stages of IOC. Furthermore, the

researcher presented the facilitation process in a visual format (*e.g.,* Figures and Charts) to the core project team, which received positive feedback regarding its feasibility, logical flow, and overall impact on facilitating the IOC.

6.4.3. Practical considerations for executing IOCF process

A challenge encountered in performing action research to facilitate inter-organizational collaboration turned out to be the motivating of participants and aligning the researcher's objectives with those of the practitioners to implement the proposed actions. The data collected during this research suggests that this challenge is often rooted in the practitioners' primary and sometimes exclusive focus on project in terms of the project management triangle (*i.e.*, time, cost, and scope) as well as project deliverables. These tend to obscure the importance of other factors such as the collaborative relationship and the development of the collaboration process in the project. Time constraints reinforce this tendency, as they force teams to prioritize the achievement of concrete outcomes over other dimensions of the collaboration, such as the quality of the collaboration process. As one core team member of the project pointed out, "*there are lots of assignments to do for the project and the project team does not have enough time to think and discuss the collaboration.*" This continuous emphasis on immediate project demands in the forms of intermediate deliverables, though understandable, overlooks the fact that effective collaboration among practitioners is a critical determinant of project success (Molaei, Bosch-Rekveldt, & Bakker, 2019; Schöttle, Haghsheno, & Gehbauer, 2014). To enhance the effectiveness of IOC, it is crucial to balance the focus on both tangible outcomes of the IOC and the collaboration process itself.

To create a foundation for executing IOCF process, a collaboration agreement was established during the project start-up meeting. Creating the collaboration agreement by core project team, providing the team with observations based on the collaboration agreement, engaging practitioners in the development of

collaborative processes, and securing the support of the project director contribute to improving the commitment of the core project team to invest time in collaboration and the development of the collaboration process. The outcomes of this action (detailed in Section 6.4.2) indicate that when practitioners work together in a collaborative framework, they can create synergies by leveraging the distinct skills and knowledge that each party brings to the table (Emmitt & Ruikar, 2013). This benefit of collaboration became evident during the research process as the teams began to experience and recognize the value of enhanced collaboration, which has also been reflected in the outcomes of the ICAT assessment improving the sub-criterion of "recognizing the benefit of collaboration" from 3 to 4.1.

While the actions taken during the facilitation process can effectively demonstrate the benefits of collaboration to practitioners, it is crucial to consider how these insights can be translated into sustainable, practical applications that do not rely on the continuous involvement of an external facilitator. The lessons learned from this research can guide practitioners in embedding collaborative practices into their routine operations. To address this, teams could be empowered to internalize the collaboration processes developed during this research. The practices such as securing the support of top management, establishing clear collaboration agreements, and conducting team-building activities proved to be essential in overcoming the initial reluctance to focus on collaboration. These strategies can in principle be implemented by the teams themselves, without requiring an external facilitator. However, it should be reiterated that a dominant focus on project milestones could easily distract project practitioners from also focusing on these aspects.

One key finding from this research is the potential complication arising when a project team member assumes the dual role of participant and facilitator. Such duality can lead to conflicts and confusion, possibly damaging relationships within the team (Coghlan, 2007). As a result of this situation the project core

team suggested the need for an independent role to monitor and facilitate the collaboration process, *i.e.*, to include in the team a dedicated collaboration facilitator whose primary responsibility would be to oversee and facilitate the collaboration process. The presence of an independent facilitator, like a Collaboration Officer, offers several advantages: they can provide impartial and continuous feedback, help maintain the team's focus on both content and process, and mitigate the risk of bias. This approach aligns with current trends where the importance of independent facilitation and integration, as seen in projects with process managers or initiatives like Resilient Delta in which independent researchers (so-called "gluons,") play a linking role between practitioners from project partners as well as different disciplines are being used is increasingly recognized (van der Winden, 2023; Dutch Advisory Council for Science, Technology and Innovation (AWTI), 2024:33). While this role proved beneficial during the research, the need for an independent facilitator is not universal and should be considered based on the specific task, the team's dynamics, and availability of resources. It is crucial for teams to develop internal capabilities that allow them to develop and evolve collaboration independently over time.

Another important aspect that should not be underestimated turned out to be the shift from action research activities and language to activities and tasks that allowed for practical application. An important aspect turned out to be the focus on the development of the capacity in teams to self-facilitate collaboration by applying the suggested IOCF process. This could be achieved by training team members to develop collaborative techniques, providing tools and frameworks that guide collaboration (such as the ICAT developed in this research), and establishing regular reflection sessions to assess and adjust collaborative efforts without external facilitation. Time and energy are required to transition these responsibilities to internal team members and integrate the development of collaborative practices into standard operating practice in collaborative projects

so that organizations can sustain effective collaboration without a perpetual reliance on external facilitators. By embedding these practices in the structure and processes of team activities, teams can sustain and enhance collaboration autonomously, ensuring that the benefits observed during this research are maintained in future projects, thereby enhancing long-term project success.

Based on the data collected during the research, it was observed that conflicts can still arise during a project, potentially hindering IOC, even when collaboration within the project core team is facilitated. The assessment conducted using the ICAT, along with follow-up interviews, indicates that the conflicts had their roots in poor levels of collaboration in the high-level management team (the steering committee, as depicted in Figure 6.1). It became evident that the behavior of the high-level management team, particularly how they endorse, support, and communicate with the project core team, significantly influenced the project team. Negative attitudes towards IOC at the management level can rapidly cascade down, adversely affecting the quality of collaboration and the unity of the project core team.

Thus, focusing exclusively on the project team is insufficient to facilitate IOC. Effective collaboration requires the active engagement and commitment of high-level management, as their attitudes set the tone for the entire project. For example, it was observed that the practitioners considered themselves to belong to their parent organizations above all, rather than the project team. As such, they often referred to each other with their organization's name. As discussed in Chapter 4, unity among the practitioners from various infrastructures is one of the factors to facilitate IOC. Therefore, the suggested action was to embed the "white label" concept in the project to promote a sense of cohesion within the project team. However, although this action might strengthen the project team spirit, the absence of such practices at higher management levels hindered the development of such unity.

It is understood that without high-level management support and clear communication, project teams may struggle to maintain unity and achieve collaborative success. The relationship between the high-level management and the project core team plays a crucial role in the success of collaborative efforts. Miscommunication and lack of alignment between these levels of management can disrupt the collaboration process and damage the project's success.

While this study primarily focuses on horizontal collaboration among practitioners from various organizations, the results indicate that hierarchical relationships that do exist in the collaborative project organization have a notable impact on IOC. This finding, supported by the ICAT assessment, suggests that the facilitation of IOC requires a holistic approach, addressing both horizontal and vertical dimensions of collaboration. Beyond working with the project core team, it is crucial to engage high-level management in the collaboration process actively. This could perhaps be achieved by establishing channels of communication with top management and fostering a shared understanding of collaborative goals at the highest levels including more interaction between the project level and senior management. All of these measures could be taken to develop, ensure and if necessary, improve high-level management support and participation in collaborative initiatives.

The data collected during the research also highlight additional challenges that hinder the collaboration process. Two major issues identified were the existence of different interests among collaborators, particularly within the high-level management team of the project, and the pressure exerted by parent organizations on their representatives to prioritize their own interests. Previous studies have shown that when a party focuses solely on realizing its own interests while disregarding those of their collaboration partners, conflicts are likely to arise among collaborators (Nezami *et al*., 2022b). This dynamic was confirmed by several project team members, one of whom noted, "*During the design and development of the project, all parties attempt to achieve their own interests due*

to the pressure from their parent organizations. This is not conducive to collaboration, causes conflicts, and lengthens the decision-making process in this project."

When employees from multiple organizations participate in a collaborative project, their identities and loyalties often remain closely tied to their parent organizations (Smits, 2013; Smits & van Marrewijk, 2012). As a result, differences in culture, working attitudes, interests, and expectations tend to become apparent, which can impair the collaboration process (Nezami *et al*., 2022b; Smits, 2013). One project core team member emphasized the need to overcome these barriers by stating, "*We have to create a common soul and show the team that we all work together on one project and find a solution that is good for the project and benefits all parties.*"

To address these issues, it is essential to align the interests of each organization with the broader goals of the collaborative project. A potential solution for this issue could be creating a temporary project organization that establishes a unified project culture, shared working practices, and common rules and policies. Due to the limited time and resources in the present study, realizing a temporary project organization was not feasible; however, the researcher together with the project team attempted to establish a unified project culture and shared working practices. This, for instance, includes embedding the notion of "white label", establishing a collaboration agreement, and scheduling free-format sessions to provide an opportunity to the team to discuss their issues. Integrating the diverse knowledge and skills of the involved parties in a temporary project organization can help collaborators form a cohesive project team that is resilient to the pressures from their parent organizations (Hobday, 2000; Mphahlele-Ntsasa, 2021; Sydow & Braun, 2018). Such a project organization should focus on the collective efforts of the project members, rather than on the individual interests of the organizational entities, effectively blurring the organizational boundaries and promoting a sense of shared purpose (Sydow

& Braun, 2018). By establishing this temporary project organization, collaborators can create an environment that prioritizes the project's success over individual organizational interests. This approach not only mitigates conflicts but also streamlines decision-making processes, leading to more effective and sustained inter-organizational collaboration.

If the facilitation responsibilities are assumed by team members, it may be necessary to streamline the facilitation process, focusing on the most critical steps to align with the available resources and time constraints. For instance, while a structured training program can equip practitioners with the necessary skills to set up a facilitation process to improve collaboration, the depth of certain steps, such as conducting in-depth interviews or continuous observation, might be adjusted according to the team's capacity.

The following streamlined procedure is recommended to facilitate IOC activities, with details on each step provided in Sections 6.3 and 6.4.1:

1. **Data Gathering**: Collect data on the IOC process through observation, informal contacts, interviews, and assessment using the ICAT provided in Appendix B.
2. **Data Analysis and Interpretation**: Analyze the collected data regarding the collaboration process, making it interpretable for practitioners through charts, figures, and tables.
3. **Feedback and Prioritization**: Present the results to the project team in a feedback session. Facilitate a discussion on the current status of the IOC and assist the team in identifying and prioritizing potential collaboration issues, using methods such as the Eisenhower matrix.
4. **Solution Development**: Collaborate with the team to brainstorm feasible solutions or actions to address the identified issues.

5. **Implementation Cycle**: Plan, implement, and observe the selected solution/action. Reflect on its effects and assess whether to iterate the cycle with further improvements or to develop a new solution/action.

By consolidating the steps and emphasizing the importance of independent facilitation, this approach enhances the overall success of collaborative projects. When delegating facilitation responsibilities internally, it seems advisable to distribute tasks not to individual team members but to small groups of practitioners from different organizations in the collaboration. This approach helps to distribute responsibilities equitably and reduces the potential for bias or conflicts of interest.

6.5. Conclusions and recommendations

The development of next-generation infrastructures with high interdependencies requires dealing with complexity and several challenges in a collaborative manner. A critical aspect of collaborative projects is synergy, which is significantly related to the collaboration process. To leverage a collaborative project, particular attention needs to be paid to the collaboration process quality to attain the exchange of resources such as data, perspectives, and skills to deliver the best possible solution for the development of next-generation infrastructures. The results reveal that infrastructure practitioners mainly focus on the hard aspects of a project (*e.g.,* time and cost) and are outcome-oriented rather than process-oriented in collaborative projects.

This research also shows that the process-oriented aspects of collaboration seem less well embedded in current IOCs and that significant efforts are required to ‘push and pull’ project practitioners and project management to invest time and energy to actively and jointly measure this dimension of collaboration, reflect in particular on the collaboration process and subsequently commit to (incremental) processes of improvement cycles.

Considering that facilitating collaboration in an IOC is a process that happens over time, action-based research was performed to facilitate IOC in an interconnected infrastructure project. During action research, a synergistic collaboration environment was created to achieve innovative solutions that benefit all parties by engaging different infrastructure practitioners in the facilitating process. The improvement of the ICAT score underpins this. The results suggest that facilitating IOC cannot happen by focusing only on one level (*e.g.,* project core team). There exists a strong connection between different levels of a collaborative project organization, considerably affecting IOC. Thus, different levels of a collaborative project organization, such as the steering committee, need to be actively involved in collaborative processes.

The involvement of various organizations in collaborative infrastructure projects can cause tension and hinder the collaboration process due to differences in interests, cultures, and working attitudes. Establishing a project entity with common project goals, interests, and working practices not only reduces the parent organizations' pressure but also benefits the practitioners to collaborate as a united team for a single project. However, managing the link between the project entity and the parent organizations is a challenge that needs further research. Action research encompasses continuous observations and is a promising approach to balancing the project team's dependence on and its level of authority from parent organizations.

The dynamic nature of an IOC in infrastructure projects, involvement of several issues and successive changes during a collaborative project necessitate applying iterative processes to facilitate it. Action research normally focuses only on resolving one single issue through iterative cycles. Hence, conventional action research needs to be extended to fit addressing several issues in IOC in a finite period. The facilitation process developed in this study comprises several stages to resolve collaboration issues and assess the overall collaboration status. To this end, the status of collaboration is assessed at the beginning of each stage

and the list of issues is identified and prioritized. To resolve the prioritized issues, enhancement cycles are performed during each stage and the impact of each action is closely observed. Iterating these stages gradually facilitates the collaboration processes in interconnected infrastructure projects. In this study, the results of the second-round assessment indicate a general improvement in inter-organizational collaboration within the investigated project resulting from the facilitation process. The most notable improvements are observed in the areas of "shared vision" and "communication, which can be ascribed to the implemented actions such as "coordination and integration meeting" and using a common data platform. Despite such improvements in IOC, certain setbacks occurred regarding aspects such as "cohesion" of the project team, "attitude about other participants", and "leadership". These occurred as a result of issues which featured in the context of the functioning of the project team. Events in the high-level management of the project and conflicts of interest among organizations thus influenced the collaborative process. Addressing these challenges in the subsequent stages necessitates exploring feasible solutions, such as enhancing communication between the project team and high-level management and implementing conflict resolution mechanisms to resolve disagreements or misunderstandings.

The facilitation process proposed in this study emerges as a framework for addressing the multifaceted challenges inherent in collaborative projects for next-generation infrastructures. The iterative nature of the proposed facilitation process, encompassing continuous assessments and targeted enhancement cycles, reflects a dynamic response to the evolving landscape of IOC in infrastructure projects. Positive outcomes of the action research performed in this study highlight the practical efficacy of the proposed approach in fostering a collaborative environment for modern infrastructure development.

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7 Conclusions and Recommendations

This chapter synthesizes the principal insights obtained from the present study, offering an overview of the findings. The conclusions of this study offer the opportunity to concentrate key findings and draw connections across various facets, offering a nuanced perspective on the subject at hand. Additionally, this study presents a set of recommendations, serving as a roadmap for future endeavors in the field of inter-organizational collaboration in infrastructure projects. The aim is to provide readers with a comprehensive overview that fosters a deeper appreciation for the intricacies and implications of the research.

7.1. Conclusions

Design and development of resilient, flexible and strongly interconnected next generation infrastructures require close collaboration between various infrastructure owners in so-called cross-infrastructural projects. Infrastructure practitioners benefit from inter-organizational collaboration (IOC) by combining multidisciplinary knowledge and expertise, pooling resources, and sharing risk to address challenges and resource constraints and enhance organizational capabilities, create synergy, and develop innovative solutions. However, collaboration between employees of various infrastructure owners with different backgrounds, cultures, interests, and working routines and methods is challenging and it is not easily attained in practice. Therefore, establishing a collaborative environment and facilitation of IOC in interconnected infrastructure projects is required. This dissertation focuses on collaboration between infrastructure owners to design interconnected infrastructure projects and answers the main research question: **How can collaboration between infrastructure owners in interconnected infrastructure projects be facilitated?** The following sub-questions are addressed to answer the main research question.

Q1. What is the status of inter-organizational infrastructure projects (regarding collaboration and data sharing)?

To facilitate collaboration to develop inter-organizational infrastructure projects, the status of inter-organizational collaboration (IOC) and data sharing, and their relationship were investigated in literature and practice. It is understood from Chapter 2 that IOC and data sharing are essential for the successful execution of next-generation infrastructure projects. Next-generation interconnected infrastructure projects need to be designed to be more resilient and adaptable to future challenges. This requires the utilization of expertise from

infrastructure practitioners from all infrastructure perspectives and their disciplinary knowledge. This knowledge then needs to be combined to develop novel ways of dealing with interdependencies between infrastructures. New knowledge can be developed by establishing a collaborative environment and sharing data across organizational boundaries.

However, the results of this research reveal that the manner in which infrastructure owners approach the execution of interconnected infrastructure projects does not indicate in-depth collaboration. Infrastructure owners typically tend to operate independently; impeding communication, the exchange of ideas and data between practitioners, and thereby defeating opportunities to establish collaboration and solve next generation infrastructure challenges.

The results of Chapter 2 suggest that factors such as the formulation of a common goal and a shared vision, interpersonal understanding, openness, trust, and data sharing facilitate IOC. According to the results, data sharing is one of the major factors of IOC which acts as a mediating factor to enhance other factors of IOC such as common goal and interpersonal understanding. However, realizing data sharing in inter-organizational projects is challenging. Developing a collaborative environment can create a win-win situation for infrastructure owners, which in turn can facilitate data sharing.

Moreover, data sharing in inter-organizational projects faces difficulties in accessibility and availability of data, lack of digital files or the low quality of data, and the use of various data standards and formats in infrastructure organizations. The outcomes of the present study indicate that data sharing is still facing fundamental challenges and is still in its infancy. Achieving data streams in inter-organizational projects is a challenging goal that has yet to be accomplished anywhere in the world. To improve data quality and enable data sharing in collaborative projects, infrastructure organizations are advised to invest more serious efforts to improve their own data but more importantly to

invest in data sharing among infrastructure operators. As concluded in Chapter 2, the initial focus of this research is on establishing a collaborative environment and facilitating collaboration between infrastructure owners, which ultimately enhances possibilities for data sharing in interconnected infrastructure projects.

The results of Chapter 2 also provide a list of factors that contribute to the facilitation of IOC and data sharing in inter-organizational projects (IOP), including soft factors (related to the relational aspects of IOP) such as openness and trust, and hard factors (related to the structural aspects of IOP) such as agreement and policy. There are common underlying factors between collaboration and data sharing, indicating the possible relationship and interdependency between these two key goals. This highlights the significance of data sharing in fostering collaboration among infrastructure owners and emphasizes the need for a collaborative environment to facilitate data sharing in inter-organizational collaboration. Therefore, it is argued that a bilateral relationship exists between collaboration and data sharing, and that these goals are intertwined.

To create a collaborative environment which facilitates data sharing in interconnected infrastructure projects one first needs to identify the challenges and the main factors of IOC, which are discussed in the following sub-questions.

Q2. What are key challenges of inter-organizational collaboration in interconnected infrastructure projects?

To answer this sub-question, a number of infrastructure projects in the Netherlands were studied to understand the challenges of IOC. Through the case studies, the possible challenges of IOC that practitioners face in collaborative infrastructure projects were explored and described in Chapter 3. The identified challenges and issues were categorized into two dimensions: a structural dimension and a relational dimension.

The structural dimension emphasizes challenges related to rules, guidelines, and organizational structure. Aspects such as different work routines and attitudes in parent organizations, successive changes in the collaborative team, cultural differences, and the position of infrastructure organizations as monopolies play a role.

The relational dimension entails challenges such as unclarity about and existence of different interests between the collaborative organizations, the disparity of professional languages and technical terminology, the dominance and power plays of organizations within in the collaboration, disunity within the collaborative team, the pressure and demands of the parent organization, and lack of successful experience with IOC.

Recognizing these potential challenges can help infrastructure owners to prepare for future collaborations.

The two main challenges of IOC pertain to the structural dimension, which are: (1) the rules, guidelines, and organizational structure of the collaboration and (2) the discrepancy of working routines and attitudes among different infrastructure organizations. Strict rules and policies within an organization restrict the ability of infrastructure practitioners to deal with unexpected circumstances during the collaboration. For example, different interpretations of safety requirements during the design of elements of infrastructures. Varied interpretations and metrics for safety exist across organizations reflecting their adherence to different rules and guidelines established by infrastructure organizations concerning safety. The discrepancies in rules and guidelines across organizations lead to disagreements among collaborators during the design phase of infrastructure projects, thereby impeding the collaboration. To overcome these and similar structural challenges, Chapter 3 suggests the reformulation and adaptation of rules for collaborative projects, emphasizing a shift towards a more collaborative approach. This entails promoting flexibility in adapting

organizational structures and procedures to facilitate IOC in interconnected infrastructure projects. Creating a common approach and structure between various organizations involved in a collaborative project can prevent potential conflicts and enhance the synergy of collaboration. However, achieving this objective is complex and requires a continuous focus on and development of IOC in incremental steps to attain synergy.

Q3. What factors influence inter-organizational collaboration in interconnected infrastructure projects?

To answer this sub-question, the factors of IOC were identified through literature review and a Q-methodology study. The Q-method analyzed practitioners' perspectives towards IOC in the context of interconnected infrastructure projects. The results of the study which can be found in Chapter 4 revealed two distinct perspectives among practitioners: a holistic goal-oriented perspective and a people-oriented perspective.

The holistic, goal-oriented perspective highlights the necessity of setting common goals in collaborative projects and emphasizes the significance of both formal and informal communication among collaborators. The people-oriented perspective prioritizes the individual dimension of IOC such as respect and trust among collaborators to establish IOC in interconnected infrastructure projects.

Based on the insights provided by infrastructure practitioners via the Q study the main building blocks (*i.e.,* factors) of IOC could be identified. These are: *commitment, respect among people, common goal and shared vision*, and *top management support*. These factors are considered to have the potential to foster effective inter-organizational collaboration in inter-organizational infrastructure projects.

Q4. How can infrastructure practitioners assess the status of inter-organizational collaboration?

Effectively managing and facilitating IOC in interconnected infrastructure projects requires awareness of the status of collaboration (*e.g.,* strengths and weaknesses of the collaboration). Due to the dynamic nature of collaborative projects regular assessments of the status of IOC are thus required. Chapter 5 identifies the assessment criteria for such an assessment based on a systematic literature study and semi-structured interviews with interconnected infrastructure practitioners. The resulting inter-organizational collaboration assessment tool (ICAT) consists of 12 criteria and 36 sub-criteria in three categories: individual, relational, and organizational (see Table 5.3). The twelve criteria which are included in ICAT are attitude and motivation, attitude about other participants, ability to work with others, working climate, shared vision, knowledge sharing, relationship continuity, value diversity, leadership, communication, formalized procedures, and improved orientation.

The ICAT serves as a tool for practitioners to design (*ex-ante*) and subsequently assess the effectiveness and progress of collaboration on twelve different dimensions during and after (*ex-post*) a collaborative project. ICAT can also be employed to help identify and analyze underlying issues in an IOC. The assessment tool enables practitioners to monitor the status of IOC in inter-organizational infrastructure projects and assists them in debating issues, making key observations on collaboration, and making informed decisions to enhance collaboration.

The practitioners emphasized the significance of using a tool to assess IOC and expressed positive feedback on the feasibility and practicality of ICAT. Discussing the results of the assessment increases interaction and productive communication among IOC-practitioners and promotes transparency and

understanding among collaborators which in turn enhances the quality of collaboration.

Q5. How can the process of inter-organizational collaboration in interconnected infrastructure projects be facilitated?

It was acknowledged that the process of IOC has a dynamic nature and requires the collective efforts of multiple organizations and the employees from these organizations working in collaboration to facilitate it. To address this in the practice of an interconnected infrastructure project, it was proposed that utilizing action research as a method would be a promising approach to facilitate the process of IOC. Through the previous chapters, it has been learned that IOC faces several issues affecting the process of collaboration. Chapter 6 indicates the application of ICAT in an interconnected infrastructure project to assess the status of IOC and identify the underlying issues. Identifying the issues and acting upon them enable the infrastructure practitioners to structure and develop collaboration. However, conventional action research mainly focuses on addressing only one specific issue to improve. Therefore, to facilitate IOC, relying on the current approach of action research is not possible. Chapter 6 describes the extension of the action research process to fit with the purpose of this chapter.

This study employs an alternative approach and proposes a process to improve collaboration, IOC facilitation process (IOCF), which is shown in Figure 6.2. This iterative approach towards the improvement of collaboration comprises several stages. Each stage includes four general steps: data gathering, data analysis, feedback, and a subsequent enhancement cycle. The proposed process can benefit infrastructure practitioners by evaluating collaboration at both the level of a specific issue as well as on the level of the overall collaboration. This approach includes formative evaluations which are

conducted during the process on specific issues and summative evaluations which are conducted to assess the overall impact of actions on IOC. The IOCF process provides a more comprehensive understanding of the collaboration and involves iterative cycles of collaboration and assessment, aiming at gradual improvement of IOC. This offers a practical approach to practitioners to develop collaboration in interconnected infrastructure projects. In Chapter 6, a detailed explanation of the implementation of the IOCF process, utilizing ICAT, is presented. The IOCF process was also introduced to the core project team, and it received favorable feedback regarding its feasibility, coherent structure, and overall positive influence on the IOC.

7.2. General conclusions

The main objective of this research is to improve collaboration between practitioners from infrastructure owners to help them design and develop next-generation infrastructures. To reach the aim of this research and address the main research question, the sub-research questions were investigated and answered in each chapter and has been summarized in the previous sub-section (7.1).

The main research question, “How can collaboration between infrastructure owners in interconnected infrastructure projects be facilitated?”, is addressed through a multifaceted approach. To facilitate collaboration, it is key to raise awareness of the need for improved inter-organizational collaboration and to gather data on how practitioners experience this collaboration (via the ICAT tool). This data provides essential input for targeted improvement efforts during interconnected infrastructure projects. Continuous improvement is established through short, iterative processes (using the IOCF process) that engage practitioners directly in identifying and developing specific tailor-made improvements in the collaboration. Incorporating direct feedback from practitioners via ICAT ensures that specific interventions improve collaboration. Additionally, a critical finding is that effective collaboration requires

organizations to optimize their internal processes, such as data management and communication structures, before engaging in inter-organizational efforts. By aligning organizational goals with collaborative objectives and conducting readiness assessments, organizations can create the conditions for successful, sustained collaboration. Together, these strategies support enhanced inter-organizational collaboration for designing and developing next-generation infrastructures.

Based upon these findings, the following statements can be formulated about inter-organizational collaboration in interconnected infrastructure projects.

1. *Fostering collaboration and data sharing among Infrastructure organizations is key to develop next-generation infrastructure.*

The intricate and interconnected nature of infrastructure projects requires diverse disciplines from different infrastructure operators to come together and collaborate. However, findings reveal that the full potential of inter-organizational collaboration has not been realized yet in infrastructure projects that have been researched in this study. The research, specifically detailed in Chapter 2 and Chapter 3, highlights several reasons for this, including the fragmented and siloed approach of infrastructure organizations, lack of data sharing, divergent interests and incentives among organizations, cultural differences, and discrepancy of working routines and attitudes within different infrastructure organizations. The road ahead involves not only acknowledging these challenges but actively working towards a future where infrastructure projects thrive on collective synergy and shared resources. It is beneficial to address these challenges by fostering an enhanced collaborative environment among infrastructure organizations. Several factors were identified in this research to facilitate collaboration and resource sharing, particularly in terms of data, among infrastructure owners. Establishing a collaborative environment among infrastructure organizations, by implementing the factors outlined in this

research, offers an opportunity to extract more benefits from inter-organizational collaboration in infrastructure projects.

2. *Infrastructure organizations that engage in next-generation infrastructure projects require new forms of collaboration which co-evolve and allow for adjustment as projects evolve.*

Infrastructure organizations tend to function and operate in a structured and procedural environment and have developed some bureaucratic working cultures to manage these environments. In many ways, infrastructure organizations have developed very different ways of working. This becomes prominent in inter-organizational collaborative efforts and when issues such as data sharing among infrastructure organizations arise as part of the collaborative process. Increasing dynamics posed by trends such as climate change and changing societal preferences, introduce additional challenges for infrastructure operators to adjust their inward-focused modes of operation (both towards their own organizations as well as their own infrastructure sector) to outward-focused modes to suit new demands and requirements. These modes of working are different and currently feature in a relatively small part of the activities of the infrastructure operators. Revising the infrastructure organizations' policies and accommodating more flexibility to the organizational structures and procedures can support and facilitate inter-organizational collaboration. This amendment can also relieve the pressures of parent organizations on project teams during a collaborative project.

3. *Next generation infrastructure projects require stronger horizontal forms of collaboration which neutralize the influence of diverging organizational interests and focus on the continuous alignment of interests of the parental infrastructure organizations.*

Collaboration between infrastructure organizations is a horizontal type of collaboration with a more or less equal power relationship. However, realizing

such equality is challenging in practice. Organizations that possess a large part (*e.g.* in terms of territory or scope) of the project, financial resources, or affiliations with governmental entities, may experience an augmented perception of increased power and influence in the context of collaborative endeavors. However, such a perception induces an unequal power balance between the collaborators and more often than not hinders rather than enhances the realization of the maximum potential of IOC. Furthermore, infrastructure practitioners currently tend to prioritize organizational goals and interests over mutual project goals, which can ultimately lead to suboptimal project outcomes. This issue can be related to the pressure of parent organizations to safeguard own interests at the expense of collaborative project interests. Aligning the interests of one's own infrastructure organization with those of the partners in the collaborative project and creating a temporary project organization, can benefit collaborators in building a cohesive project team and reduce the influence of parent organizations. Moreover, establishing such a project organization with a united entity can enhance the synergy in an IOC. However, in reality, it turns out to be very complex and there are numerous challenges that need to be overcome. For instance, as discussed in Chapter 6, conflicts of interest among the high-level management, such as steering committee, valuing their own organization's interest can propagate to the project team and hinder collaboration. Working systematically towards a shared understanding of a project's goals and a collaborative approach is needed to address such issues.

4. *Novel forms of horizontal inter-organizational collaboration are needed to move beyond a silo-mentality in infrastructure projects.*

Creating common collaborative processes and procedures and utilizing collaborative tools and platforms can be beneficial to establish a collaborative project organization. However, this research showed that in the projects that were studied for this research, practitioners currently have a preference for working

on a common project primarily on their own, relying on their own methods and procedures. A silo mentality exists among infrastructure practitioners, which hinders the establishment of a truly collaborative working environment in inter-organizational infrastructure projects that have been researched.

5. *Identify and isolate specific "interfaces" during the design phase in next generation infrastructure projects for which horizontal IOC is required.*

Next-generation infrastructure projects could identify "interfaces" and explicitly demarcate a part of the project for which inter-organizational collaboration would be required and developed. Instead of distributing and assigning separate responsibilities for the project, the proposed approach would identify a part of the project (typically where two infrastructures interconnect) which is assigned shared ownership. This interface needs to be identified during the design phase by infrastructure practitioners. IOC is expected to be developed and improved especially with regard to this "interface".

6. *Success in next generation infrastructure projects requires an integral, holistic perspective on IOC.*

Different levels of the collaborative project organization are highly interdependent, considerably affecting IOC. High-level management (*e.g.*, a steering committees or joint board) has a significant influence on the success of inter-organizational collaborations. First of all, by establishing the conditions under which collaboration can take place, and more importantly by promoting flexibility, offering support, and active involvement in collaborative processes. Facilitating IOC in infrastructure projects requires focusing on multiple organizational levels and this extends beyond the conditions at the level of the project core team.

7. *Invest in capturing lessons learned from IOC in next generation infrastructure projects.*

One of the key benefits of IOC is the opportunity that it provides for mutual learning and the development of skills and expertise across organizations through sharing data and past experiences. This can be achieved, for instance, through the joint efforts of practitioners to design and implement infrastructure projects collaboratively. By working together on a project and interacting throughout its duration, practitioners can share data and gain explicit and tacit knowledge. Such practices of data sharing and mutual learning at an inter-organizational level can lead to the acquisition of new insights that are applicable for future collaborations and project implementations even at the organizational level. Moreover, the significant benefits achieved through an IOC are often motivating for the involved organizations to pursue future collaborations. This further confirms the existence of a bilateral relationship between collaboration and data sharing.

8. *Synergize outcome-oriented and process-oriented perspectives from IOC in next-generation infrastructure projects.*

The observations in this study reveal that infrastructure practitioners are generally primarily outcome-oriented and focus mainly on the performance of the project and its hard aspects (*e.g.,* time and cost). They focus less on collaborative relationships and collaboration processes in interconnected infrastructure projects. Although some practitioners find the collaborative relationship and collaboration process (*i.e.*, soft factors) critical for the success of an inter-organizational project, these constitute a small minority. The dichotomy highlights that various viewpoints can exist in a team towards IOC and that these viewpoints are equally important and appreciable. Accounting for such viewpoints aids to understand how project team members perform their tasks in a collaborative inter-organizational environment and what aspects of

IOC require more attention. An effective collaboration can result in project success, less rework and project delays. Facilitating IOC not only enhances the project performance of the infrastructure organizations but also enables them to leverage the complementary resources, multidisciplinary knowledge, and skills of the participating organizations. This can result in synergistic collaboration and the attainment of the best possible solutions for infrastructure projects as shown in Chapter 6.

9. *IOC requires continuous attention and resources in next-generation infrastructure projects.*

The dynamic nature of IOC in infrastructure projects, involvement of several issues, and successive changes during a collaborative project necessitate applying iterative processes to facilitate IOC. The process developed in this study (see Figure 6.2) comprises several stages that aim to help and support practitioners to address and resolve collaboration issues and assess the overall collaboration status. The results of the ICAT and the feedback received from the project team indicate that the implementation of the IOC facilitation process (IOCF) has enhanced collaboration. Chapter 6 demonstrates how iteration of these stages can facilitate incremental improvement of collaboration processes in interconnected infrastructure projects.

10. *IOC in next generation infrastructures requires synergy and breaking down organizational silos through leadership and conscious staffing decisions.*

Leadership plays a pivotal role in promoting a collaborative culture. Leaders who emphasize the need for synergy and exemplify collaborative behavior can influence their teams to adopt similar practices. The key to unleash such potential in IOC is to train them and cultivate a collaborative mindset among personnel. Next, bring involved practitioners together and facilitate collaboration among them. The promotion of cross-functional teams especially those in the

aforementioned “interfaces” can serve as an effective strategy for breaking down silos. This promotes a broader understanding and enhances the collective skill set of the team, thereby facilitating collaborative decision-making.

7.3. Scientific contribution and practical implications

Managing next-generation infrastructures with increasing complexity and interconnectivity has gained significant attention from both academia and industry. This research aims to enable infrastructure owners to collaborate effectively in the design and development of future infrastructure projects. It addresses research gaps in horizontal collaboration, particularly in the context of infrastructure projects.

This research makes a scientific contribution by identifying and analyzing key factors associated with collaboration and data sharing in inter-organizational infrastructure projects. In contrast to previous studies that focused on vertical forms of collaboration and relationships between infrastructure owners and contractors, the focus of the present study is on the horizontal dimension of collaboration in interconnected infrastructure projects. This dimension of collaboration is addressed less specifically in literature. This research emphasizes the crucial role of effective collaboration for the successful execution of inter-organizational projects, while also highlighting the significance of managing and sharing of data. It also offers an understanding of the relationship between collaboration and data sharing in inter-organizational infrastructure projects. The outcome of the present study reveals that effective collaboration between different organizations is required for data sharing, which complements the previously acclaimed notion that data sharing is a prerequisite for collaboration. The study demonstrates the intertwined nature of collaboration and data sharing.

The findings indicate that there are many challenges to be addressed when it comes to collaborating with other infrastructure organizations on a project and

sharing data related to such a project. This study identified challenges and issues of IOC in interconnected infrastructure projects which are categorized into two dimensions: a structural dimension (such as rules, guidelines, and organizational structure, discrepancy of working attitudes in different infrastructure organizations) and relational dimension (such as dominant position of organizations, unsuccessful previous experience). The recognition of these challenges can help practitioners better understand their own organization's approach towards collaborative efforts and data sharing across their organizational boundaries. Recognizing possible challenges beforehand helps infrastructure owners and policymakers to foresee them adequately so that necessary steps can be taken before a collaborative project begins or during its execution phase if needed.

The research provides a comprehensive overview of the factors affecting inter-organizational collaboration in interconnected infrastructure projects. It identifies two distinct perspectives on IOC, namely a "holistic, goal-oriented" perspective and one which is more "people-oriented". Practitioners can utilize these findings as building blocks for establishing a collaborative environment at the project level by focusing on different aspects of IOC such as individual, relational, and organizational collaborative capacity. The holistic goal-oriented perspective values factors such as a common goal, a shared vision, and the importance of formal and informal communication between collaborators. The people-oriented perspective prioritizes the individual dimension of IOC such as respect and trust among the collaborators, highlighting the significance of interpersonal dynamics.

The study results emphasize that various perspectives on collaboration coexist among practitioners in inter-organizational infrastructure projects. Effective management of diverse perspectives and viewing them as complementary is beneficial for achieving synergistic collaboration within a project. By acknowledging and understanding these varied perspectives in a

collaborative team, practitioners can address potential disparities in the beliefs of IOC and embed and enhance key IOC factors within teams. This involves targeted training programs aimed at equipping team members with the skills and understanding to navigate and bridge any gaps in collaborative capacity. Incremental improvement can facilitate inter-organizational collaboration in interconnected infrastructure projects.

The study has identified the criteria for assessing the status of horizontal forms of IOC, particularly in the context of infrastructure projects. The assessment criteria identified through this study form the foundation for developing an effective IOC by providing a practical assessment tool. The assessment tool enables practitioners to monitor the status of collaboration between infrastructure owners and assists them in making informed decisions and enhancing collaboration during a project. It enables organizations to identify areas where they need improvement or additional resources when it comes to collaborating with other parties on complex infrastructure tasks.

This research proposes the development of a participatory approach of involving people who need to collaborate in interconnected infrastructure projects, with particular focus on IOC facilitation. The study highlights the dynamic nature of IOC in infrastructure projects and emphasizes the need for iterative processes to drive continuous improvement of IOC. The proposed approach provides a systematic and structured way to facilitate IOC in infrastructure projects through a multi-stage process.

To develop the participatory approach, the study employs an action research method for developing processes that stimulate IOC and are suitable for daily practice. By assessing the collaboration at the beginning of each stage and identifying and prioritizing issues, practitioners can focus their efforts on resolving the most critical issues and improve collaboration.

The proposed approach has practical implications for practitioners involved in infrastructure development and seeks to activate them to enhance collaboration and alignment and achieve innovative solutions and deliver projects that benefit all parties involved.

7.4. Recommendations for future research

Based on the findings and implications of this study, several recommendations can be made for future research in the area of inter-organizational collaboration.

While this study has highlighted the importance of internal processes such as data management, communication channels, and organizational adaptability, further investigation is needed to focus on exploring the organizational preconditions that influence successful inter-organizational collaboration, particularly in the context of next-generation infrastructure projects. Additionally, research could examine how organizations can assess their readiness for collaboration more systematically, including the development of tools that evaluate technological capabilities, resource alignment, and leadership commitment. Understanding these preconditions in greater depth will enable organizations to position themselves more strategically for collaboration, addressing gaps in knowledge and providing a stronger foundation for inter-organizational collaborations.

The findings presented in Chapter 4 suggest the presence of a potential correlation among the factors influencing IOC within the context of interconnected infrastructure projects. To deepen our understanding, it is recommended that subsequent studies adopt a relational modeling approach to scrutinize the interplay and magnitude of effects among these identified factors. By investigating the relationships between these factors, researchers can unravel the complexities of how each factor influences and interacts with other factors within the realm of IOC. Considering the potential impact of cultural differences and divergent perspectives across different countries, it is essential to expand the

scope of research to include infrastructure organizations from diverse cultural backgrounds. This expansion is crucial because cultural variations may introduce additional dimensions to the factors influencing IOC. By incorporating a broader international perspective, future research can provide a more comprehensive understanding of how practitioners' perspectives on IOC may differ across various cultural and organizational contexts. Moreover, the inclusion of infrastructure organizations from different countries allows for the identification of commonalities and differences that may exist in the factors influencing IOC across diverse cultural settings. This comparative analysis can offer insights into the generalizability of IOC factors, aiding in the development of more robust theoretical frameworks that can be applied across a broader spectrum of organizational and cultural contexts.

Finally, the study has significant implications for further research in the area of infrastructure development. The multi-stage facilitation process (IOCF) developed in this study can serve as a framework for future research to explore how IOC can be facilitated in different contexts and to identify best practices for enhancing collaboration among different infrastructure practitioners.

Appendices

Appendix A. Results of Q-study

Table A1. List of concourses based on three resources. The items highlighted in gray indicate the factors that were excluded from Q-set.

Number	Factors	Literature	Preliminary Research	Case Study	
1	Communication	x	x	x	3
2	Commitment	x	x	x	3
3	Common goal and shared vision	x	x	x	3
4	Collaborative leadership	x		x	2
5	Conflict resolution	x			1
6	Technical and substantive knowledge	x		x	2
7	Resource sharing	x	x	x	3
8	Trust	x	x	x	3
9	Equality	x	x	x	3
10	Clarify roles and responsibilities	x		x	2
11	Relationship orientation	x		x	2
12	Organizational culture	x		x	2
13	Collaborative agreement	x	x	x	3
14	Collaborative tools	x		x	2
15	Adaptability	x		x	2
16	Teamwork and cooperation	x	x	x	3
17	Top management support	x	x	x	3
18	Early involvement of key participants	x	x	x	3
19	Respect	x	x	x	3
20	Willingness	x	x	x	3
21	Interpersonal understanding	x	x	x	3
22	Joint decision-making	x	x	x	3
23	Team building	x			1
24	Individual competency	x	x	x	3
25	Collaborative process	x	x	x	3
26	Regulations and government support	x	x		2
27	Internal administration of each organization	x			1
28	Team motivation and incentives	x			1
29	Share pain and gain	x	x		2
30	External communication	x			1
31	Group process skills	x			1
32	Compatibility of management styles	x			1
33	Unity (No organizational boundaries)	x	x	x	3
34	Time of inter-organizational collaboration	x			1
35	Physical proximity	x			1
36	Expectations of collaborating organizations	x			1
37	Alignment of incentives	x			1
38	Iteration of inter-organizational collaboration	x			1
39	Uncertainty conditions of collaborative work	x			1
40	Social and economic conditions	x			1
41	Openness		x	x	2
42	Safe environment		x	x	2
43	Getting to know each other		x	x	2
44	Having fun		x	x	2
45	Consistent team members		x		1
46	Awareness of each other work			x	1
47	Choosing the right/impactful people		x		1

Table A2. Identified factors of IOC based on the literature review. (The Frequency in the Table Represents the Number of Times a specific Factor was mentioned.)

Number	Factors of IOC Based on the Literature	Frequency
1	Communication	7
2	Commitment	7
3	Common goal and shared vision	6
4	Collaborative leadership	5
5	Conflict resolution	5
6	Technical and substantive knowledge	5
7	Clarify roles and responsibilities	5
8	Trust	5
9	Organizational culture	4
10	Resource sharing	4
11	Relationship orientation	4
12	Collaborative agreement	4
13	Collaborative tools	4
14	Adaptability	4
15	Collaborative process	3
16	Interpersonal understanding	3
17	Teamwork and cooperation	3
18	Top management support	3
19	Early involvement of key participants	3
20	Respect	3
21	Willingness to collaborate	3
22	Joint decision-making	2
23	Equality	2
24	Team building	2
25	Individual competency	2
26	Regulations and government support	2
27	Team motivation and incentives	2
28	Share pain and gain	2
29	Expectations of collaborating	2
30	External communication	1
31	Group process skills	1
32	Compatibility of management styles	1
33	No organizational boundaries (unity)	1
34	Time of inter-organizational collaboration	1
35	Physical proximity	1
36	Internal administration of each organization	1
37	Social and economic conditions	1
38	Iteration of inter-organizational collaboration	1
39	Uncertainty conditions of collaborative work	1
40	Equity	1

Table A3. Identified factors of IOC based on the preliminary research.

Number	Factors of IOC Based on the Preliminary Research	Frequency
1	Common goal and shared vision	9
2	Teamwork and cooperation	8
3	Openness	7
4	Interpersonal understanding	7
5	Collaborative agreement	6
6	Willingness	6
7	Resource sharing	5
8	Trust	5
9	Communication	5
10	Equality	5
11	Safe environment	5
12	Top management support	4
13	Commitment	4
14	Respect	4
15	Joint decision-making	4
16	Unity	3
17	Choosing the right/impactful people	3
18	Getting to know each other	3
19	Individual competency	3
20	Early involvement of key participants	2
21	Consistent team members	2
22	Regulations and government Support	2
23	Share pain and gain	2
24	Collaborative process	2
25	Having fun	2

Table A4. Identified factors of IOC based on case studies.

Number	Factors of IOC Based on the Case Study	Frequency
1	Communication	13
2	Teamwork and cooperation	9
3	Resource sharing	9
4	Getting to know each other	8
5	Openness	7
6	Interpersonal understanding	7
7	Trust	6
8	Organizational culture	6
9	Collaborative tools	6
10	Equality	6
11	Collaborative agreement	5
12	Collaborative process	4
13	Common goal and shared vision	3
14	Individual competency	3
15	Early involvement of key participants	3
16	Safe environment	3
17	Willingness	3
18	Respect	3
19	Joint decision-making	3
20	Clarify roles and responsibilities	3
21	Adaptability	2
22	Commitment	2
23	Technical and substantive knowledge	2
24	Top management support	2
25	Unity	2
26	Awareness of each other work	2
27	Collaborative leadership	1
28	Relationship orientation	1
29	Having fun	1

Table A5. Z-score and Q-sort values for the two perspectives.

Number	Statement	Perspective 1		Perspective 2	
		Z-Score	Q-Score	Z-Score	Q-Score
1	Commitment	1.86	1	1.05	5
2	Respect among people	0.66	11	1.78	1
3	Willingness to collaborate	1.15	4	1.02	6
4	Interpersonal understanding	−0.12	21	0.88	7
5	Understanding the mutual expectations	0.85	9	1.37	3
6	Individual competency for collaborative tasks	0.65	12	−0.16	21
7	Professional and technical expertise of collaborators	0.29	17	−1.18	32
8	Previous inter-organizational collaboration experience	−1.27	32	−1.13	31
9	Getting to know each other	−1.10	29	0.31	17
10	Having fun	−0.43	24	0.74	10
11	Relationship building	−0.28	22	−0.08	19
12	Unity with no organizational boundaries	−1.37	34	−1.08	30
13	Early involvement of key participants	0.97	6	0.86	8
14	Reciprocated Trust	0.60	14	1.36	4
15	Openness	0.85	8	0.44	15
16	Adaptability	0.12	19	0.26	18
17	Common goal and shared vision	1.79	2	0.44	14
18	Inclusive coordination and teamwork	0.33	16	−0.23	24
19	Joint decision-making	0.61	13	−0.13	20
20	Management via a common collaborative process	−1.50	35	−0.66	26
21	Equality between collaborating parties	−0.35	23	−1.70	35
22	Balanced relationship	−1.07	28	−0.87	28
23	Shared organizational culture	−1.29	33	−2.10	36
24	Understanding of different organizational culture	−0.80	26	0.62	12
25	Collaborative leadership	0.27	18	−0.18	22
26	Top management support	1.06	5	1.56	2
27	Frequent, high-quality, professional communication	0.92	7	0.52	13
28	Direct informal communication	1.18	3	−0.71	27
29	Safe environment	0.35	15	0.85	9
30	Resource sharing	−1.21	31	−0.91	29
31	Clear definition of roles and responsibilities	0.84	10	−0.58	25
32	Collaborative legal agreement	−1.02	27	−1.53	33
33	Collaborative common ground rules	−0.00	20	−0.23	23
34	Collaborative tools and technologies	−1.19	30	−1.57	34
35	Regulations and government support	−1.89	36	0.64	11
36	Share pain and gain	−0.48	25	0.34	16

Appendix B. Inter-organizational Assessment Tool (ICAT)

Inter-organizational Collaboration Assessment Tool (ICAT)		
Please rate the following criteria by assigning a score of 1 = Strongly disagree, 2 = Disagree, 3 =Neither agree nor disagree, 4 = Agree, 5 = Strongly agree		
#	**Criteria**	**Scores**
(ICC). Individual Collaborative Capacity		
i.1	**Attitudes and motivations**	
i.1.1	The project team members are committed to devoting skills, knowledge and resources to the collaboration.	1 2 3 4 5
i.1.2	The project team is willing to work with each other.	1 2 3 4 5
i.2	**Attitudes about other project participants**	
i.2.1	The organizations and team members in our project have a collaborative culture rather than a competitive culture.	1 2 3 4 5
i.2.2	Project team members trust the other (subproject) team members	1 2 3 4 5
i.3	**Ability to work with others**	
i.3.1	The project team member can constructively deal with the conflicts associated with other subproject teams	1 2 3 4 5
(RCC). Relational Collaborative Capacity		
r.1	**Working climate**	
r.1.1	There is cohesion between the different (sub) project teams, and we work together as a unit.	1 2 3 4 5
r.1.2	The relevant members are involved in our collaborative project.	1 2 3 4 5
r.1.3	In our project, we recognize the benefit of working together with other subproject teams.	1 2 3 4 5
r.1.4	There is mutual trust between the organizations.	1 2 3 4 5
r.1.5	In our project, there are no hidden agendas among (sub) project teams.	1 2 3 4 5
r.1.6	We support the coordinators of our collaborative project.	1 2 3 4 5
r.1.7	In our project, we support and help each other to achieve common goals.	1 2 3 4 5
r.1.8	In our project, we collaboratively adapt ourselves to unforeseen incidents/changes.	1 2 3 4 5
r.1.9	We appreciatively welcome new information and innovative ideas.	1 2 3 4 5

r.2	Shared vision	
r.2.1	In our project, we have a mutual understanding of the goals, related activities and interdependencies between the activities.	1 2 3 4 5
r.2.2	In our project, we have a common mission and vision established between the different (sub)project teams.	1 2 3 4 5
r.2.3	In our project, we have joint working processes (such as jointly reviewing plans and the requirements, performing, monitoring, controlling and reporting together, and joint decision making).	1 2 3 4 5
r.2.4	Contributions from different (sub)project teams are aligned and their work meets the expectations.	1 2 3 4 5
r.3	**Knowledge sharing**	
r.3.1	In our project, we motivate knowledge collection and distribution with other subproject teams.	1 2 3 4 5
r.3.2	In our project, we are able to transfer explicit and tacit knowledge with other subproject teams.	1 2 3 4 5
r.3.3	In our project, we have gained and applied new knowledge from the representatives of other organizations.	1 2 3 4 5
r.4	**Relationship continuity**	
r.4.1	In our project, we feel that our organizations are sufficiently involved (engaged) in various steps of the project.	1 2 3 4 5
r.4.2	Beyond this project, we are willing to work with each other in future.	1 2 3 4 5
r.5	**Value diversity**	
r.5.1	The project team understands and examines the perspectives of team members from other organizations in the project.	1 2 3 4 5
r.5.2	Cultural differences of organizations are appreciated by the project team.	1 2 3 4 5
(OCC) Organizational Collaborative Capacity		
o.1	**Leadership**	
o.1.1	Senior management connects the members to the network and is driving the relationship to achieve outcomes.	1 2 3 4 5
o.1.2	Senior management is committed to providing necessary resources and supporting the collaboration.	1 2 3 4 5
o.1.3	Senior management of both organizations actively works together to resolve potential conflicts when needed.	1 2 3 4 5

o.2	Communication	
o.2.1	We have a free flow of communication between all members of the project team; all members can access all information.	1 2 3 4 5
o.2.2	In our project, we have a system able to facilitate high volumes of information sharing.	1 2 3 4 5
o.2.3	In our project, we are able to share our ideas openly with team members from other organizations.	1 2 3 4 5
o.2.4	In our project, we communicate regularly with team members from other organizations.	1 2 3 4 5
o.3	**Formalized procedures**	
o.3.1	In our project, the roles and responsibilities of team members are clarified.	1 2 3 4 5
o.3.2	In our project, there are clear procedures and guidelines for all of the processes involved in collaborative work (*e.g.* interagency agreements, decision-making, conflict resolution).	1 2 3 4 5
o.3.3	In our project, there are clear values, norms and rules that establish/determine the collaboration and interaction between the organizations (*e.g.* Collective approach, no blame culture, win-win, communication with openness).	1 2 3 4 5
o.4	**Improved orientation**	
o.4.1	In our project, our actions, needs and resources are regularly monitored to meet common goals.	1 2 3 4 5

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Maryam Rikhtegar Nezami

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List of Publications

1. **Nezami, M. R.**, de Bruijne, M.L.C., Hertogh, M.J., & Bakker, H.L. (2024). Assessment criteria for inter-organizational collaboration in interconnected infrastructure projects. *Engineering, Construction and Architectural Management, 31*(9), 3456–3478. DOI: 10.1108/ecam-11-2022-1109

2. **Nezami, M. R.**, de Bruijne, M.L.C., Hertogh, M.J.C.M., Bakker, H.L.M. (2023). Inter-Organizational Collaboration in Interconnected Infrastructure Projects. *Sustainability*, *15*(8), 6721. DOI: 10.3390/su15086721

3. **Nezami, M. R.**, De Bruijne, M. L. C., Hertogh, M. J. C. M., & Bakker, H. L. M. (2022). *Identifying the key challenges of inter-organisational collaboration*. Paper presented at the European Academy of Management (EURAM) conference 2022, Winterthur, Switzerland, June 2022.

4. **Nezami, M. R.**, De Bruijne, M. L. C., Hertogh, M. J. C. M., & Bakker, H. L. M. (2022). Collaboration and Data Sharing in Inter-Organizational Infrastructure Construction Projects. *Sustainability*, *14*(24), 16835. DOI: 10.3390/su142416835

5. Sohi, A. J., **Nezami, M. R.**, Bakker, H., & Hertogh, M. (2020). Inter-Organizational Co-Creation: An Approach to Support Energy Transition Projects. In *Research on Project, Programme and Portfolio Management*, *Lecture notes in management and industrial engineering* (pp. 151–166). Springer, Cham. DOI: 10.1007/978-3-030-60139-3_11

6. **Nezami, M. R.**, Sohi, A. J., de Bruijne, M.L.C., Hertogh, M.J.C.M., Bakker, H.L.M. *On the Relationship between Data sharing and Collaboration in Inter-organizational Projects*. Paper presented at the European Academy of Management (EURAM) conference 2020, Online event, December 2020.

About the Author

Maryam Rikhtegar Nezami was born in 1989 in Tabriz, Iran. She earned a bachelor's degree in industrial engineering from Tabriz University in 2013 and later pursued a master's in technology management at the University of Tehran. In 2016, she moved to the Netherlands to further her studies, completing her Master's graduation project in collaboration with Delft University of Technology. Her thesis, Specifying the Preferences to Exploit an Integrated Community Energy System (ICES) Using Automated Modeling of the Collective Agreement, explored innovative approaches to optimizing complex integrated community energy systems.

In May 2018, Maryam began her PhD in the Integral Design and Management section of the Faculty of Civil Engineering and Geosciences at Delft University of Technology. Her research was part of the Next Generation Infrastructure initiative, funded by The Dutch Research Council (NWO) and supported by major industry partners, including Schiphol, Rijkswaterstaat, ProRail, Vitens, and Alliander. During her doctoral studies, she supervised multiple master's students, collaborated with key infrastructure organizations in the Netherlands, and presented her research at national and international conferences. Her work has also been published in scientific journals.

Passionate about bridging research and industry, Maryam currently works as a project manager at DXC Technology, applying her expertise in technology management and infrastructure systems to lead impactful projects. She can be reached at M.Rikhtegarnezami@tudelft.nl or Nezami.maryam@gmail.com.

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