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Collaboration and Data Sharing in Inter-Organizational Infrastructure Construction Projects

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Abstract: 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.

Keywords: interconnected infrastructure; inter-organizational projects; inter-organizational collaboration; horizontal collaboration; data sharing; inter-organizational project management

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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 [1]. 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 [2]. 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 [3].

The design, development, and implementation of sustainable and resilient infrastructures require new ideas, business models, and multi-disciplinary data and knowledge, which generally cannot be realized at an organizational level because infrastructures are often interconnected, share interfaces, and their performance depends on one another [4,5]. 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 [6,7]. 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 [7].

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 [8,9]. Inter-organizational collaboration (IOC) supports the development and realization of IOPs for which multi-disciplinary data and knowledge are essential [10,11]. IOC can facilitate the communication and exchange of data across organizational boundaries by creating an open working relationship among participants [12]. 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 [13]. However, the results of IOC assessments indicate high rates of failure and dissatisfaction in practice [14,15]. Previous studies suggest poor data sharing in infrastructure projects as a critical element that can adversely affect the collaboration of project parties [13,16]. The design, development, and implementation of infrastructures strongly rely on data to deliver services at a desirable level of quality [17,18]. Sharing data between infrastructure organizations supports the completion of IOPs within time and budget constraints [19,20]. The flow of data across organizational boundaries is considered important for the realization of IOPs [21]. 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). Section 3 explains the research methodology, and Section 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 5 and 6, respectively.

2. Literature Review

2.1. Inter-Organizational Collaboration

Collaboration is derived from the Latin word "collaborate", meaning "work with" [22]. Wilkinson [23] 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 [24]. Close collaboration in design and development reduces lead times and improves product quality [25]. Collaboration also emphasizes the importance of people and social relationships, such as trust and commitment [26]. Collaboration is generally beneficial when a variety of data and experiences is required to realize a complex problem and jointly work to come up with solutions [27].

In the literature, collaboration is characterized by several features. First, collaboration engages organizations and interested individuals with a stake in the outcomes [28,29]. Second, collaboration requires a commitment of parties to solve problems [30,31]. Third, collaboration involves participants in an intensive and creative process, resulting in creative solutions which increase the possibility of acceptance [29,30]. Finally, collaboration contributes to achieving a consensus on issues, aims, and proposed actions [29].

Collaboration across organizations, also known as IOC, is considered indispensable to deal with complexity in infrastructure projects [32] and to develop interconnected infrastructures. Phillips and Lawrence [33] describe IOC as a collaborative relationship without a single legitimate authority but with discursive legitimacy or negotiated rules, resources, and roles. Phillips and Lawrence [33] define IOC as a "*cooperative relationship among organizations that relies on neither market nor hierarchical mechanisms of control*". Armstrong and Jackson-Smith [34] define IOC as "*the coming together, deliberation, and agreement between two or more organizations that lead to change*". Emmitt and Ruikar [35] consider IOC as a temporary activity and state that IOC is the product of multi-disciplinary and multi-skilled teams which share their resources, skills, data and knowledge to engage in collaborative practices in projects to achieve a 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 [19]. Based on these insights, an IOC is defined here as "an integral process of collaboration based on trust, honesty, and openness in which multi-disciplinary 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 [36–38]. IOC provides a framework within which participants feed resources, such as data, funding, competencies, and work methods, into a collaborative project [39]. IOC offers benefits such as new knowledge (i.e., learning from collaboration) [40,41]; efficiency, from the pooling of resources; and product or service improvement [42]. The collaboration of several organizations in a project enables practitioners to exploit the expertise and data from these different organizations to obtain mutual benefits [43,44]. During an IOC, independent organizations and individuals collaborate to seek collective goals rather than individual ones [45]. IOC also provides an opportunity to improve practices via innovative approaches and solutions developed by all participants involved in a project [46–48]. 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 [14,49]. 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 [35] emphasize the importance of factors related to tcollaboration: 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 and Lawrence [33] argue that establishing collaborative politics and agreements is one of the main challenges for IOC. The literature, thus, presumes that collaborative challenges hinder IOC [49], leading to fewer collaborations [14]. 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 [50,51]. Furthermore, collaboration has been widely studied in infrastructure supply chains [52,53] and between infrastructure owners, contractors, and design teams [54]. 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 the literature [7,55]. 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 multi-disciplinary data beyond their organizational boundaries. Therefore, managing and sharing data in inter-organizational projects constitute an important dimension of IOC.

2.2. Data Sharing

The word "data" originates from Latin and literally means "something given" [56]. Literature on data sharing identifies three key concepts: data, knowledge, and information. Abdelsayed and Navon [57] 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 [58] define data as "*abstract, formal, sometimes symbolic entities like elementary facts, letters and numbers*". Zins (2007) considers data as raw materials: 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 [59,60]. As multi-disciplinary 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 [61]. Similarly, data are needed during a construction project—from the concept phase to the execution phase [62]. Large-scale infrastructures strongly rely on data to deliver their services at a desirable level of quality [17] and for the satisfactory completion of projects [19]. Various types of data are required in the construction industry to support the design and development of sustainable infrastructures [21,63]. Generating, collecting, managing, and analyzing data are among the core management tasks, which typically take up to 70% of the management's time [64]. Due to the workload and time constraints in projects, managers prefer to focus on the main project tasks rather than data management [65,66], 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 [13]. Organizations need to establish coordination and control over data to facilitate data sharing [19].

Data sharing is often challenging in cross-functional teams, even within a single organization [67]. Despite the well-established role of data in project success, many challenges persist in data sharing among organizations [19]. 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 [57]. Data sharing is mainly restricted due to hierarchies, power relations, and confidentiality concerns [13]. Since data are valuable, sharing data across organizations can jeopardize the position of an organization, resulting in a tendency to hoard data [65,68]. Riege [65] identifies various barriers to data sharing between organizations including time limitation, cultural differences, lack of communication (which hinder the interaction of involved parties), lack of trust and a proper platform/resources to support data sharing. However, establishing a collaborative environment and close collaboration among parties can overcome barriers to data sharing and knowledge hoarding [66]. 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 [65].

One of the challenges of executing a project is that data are often not available or easily accessible in a timely fashion [69], which can cause rework, dispute, and delay [13]. Chen and Kamara [62] studied data management in construction sites and concluded that data are generally deficient in construction projects. Moreover, the effective utilization of data is a demanding task that few organizations have mastered [70]. 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 [71]. Uncertainty and imprecision of data degrade their quality and value [69]. To analyze the value of data, Titus and Bröchner [69] 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 [69]. Additionally, data need to be managed, standardized, and integrated to yield value and establish an effective collaboration of various actors as well as organizations [69,72], which is a challenge for data sharing [21].

A lack of data disrupts decision-making in construction projects [73]. Data in the construction industry has a considerable influence on the decision-making process and solution-finding [62]. The importance of data sharing to improve the performance of construction projects has been extensively underlined in the literature [62]. 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 [74,75]. Consequently, appropriate solutions for data management in construction projects are yet to be explored [62].

Data sharing across organizational boundaries is the backbone of successful projects with better performance [21]. According to Jensen and Bjørn-Andersen [76], 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 multi-disciplinary projects, efficient data management between organizations would be an effective solution [13,69]. Data sharing is, thus, recognized as one of the major factors that allow collaboration between infrastructure managers [72]. To clarify this perspective, Senescu and Aranda-Mena [77] recognized three types of data sharing: (1) within a project, (2) between projects, and (3) across firms or industries. All of these routes for data sharing should be properly paved to serve the efficient mobility of data.

Data sharing has been studied in different fields of science [57,78]. The concepts of data sharing and management have also been studied in the project management arena [61,79–81]. However, data sharing in inter-organizational infrastructure construction projects has not received much attention in the 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 fulfil 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.

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, the 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 [82].

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 1.

Table 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

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 4.

4. Results

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

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 a 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 is 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 added:

"*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 of 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, 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 1.

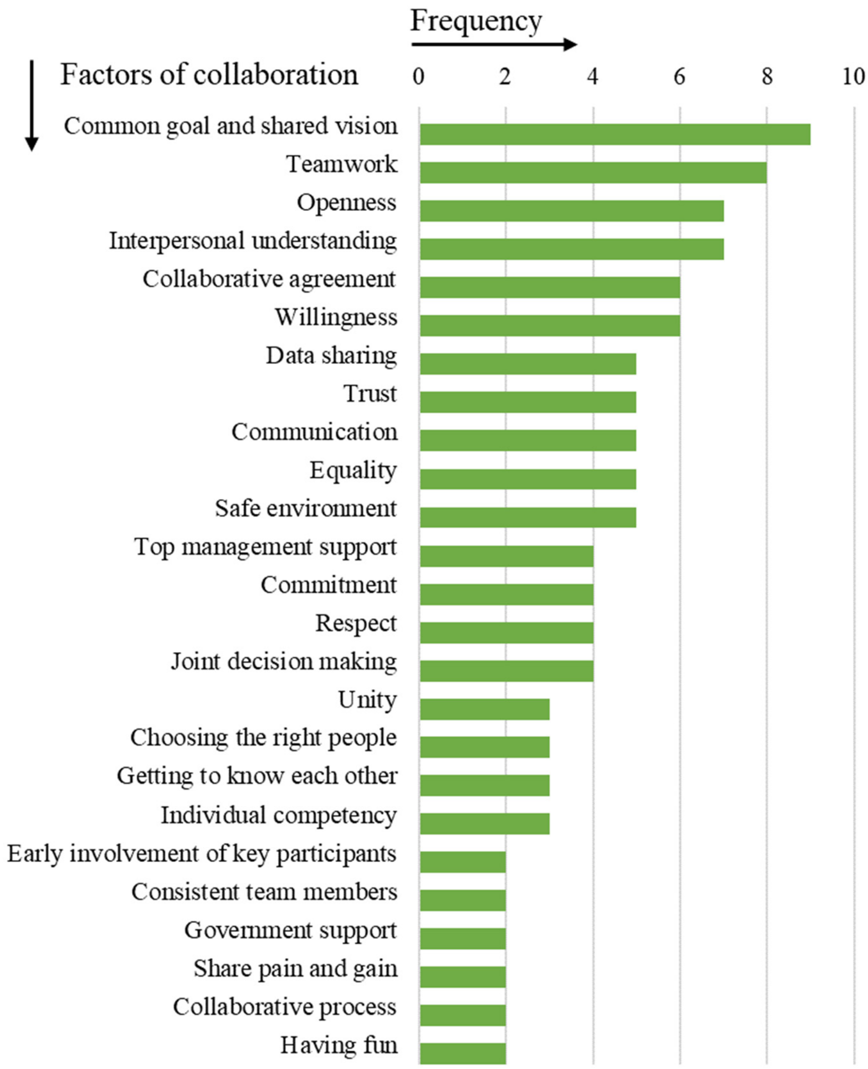

Figure 1. Factors facilitating collaboration in IOPs.

Figure 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 visions" 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 results 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 the sharing of various parties' data during collaborative work, which contributes to joint problem-solving, creating innovative solutions, and improving IOCs.

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 to 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 communication in 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 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*". Respondents thought that openness and data sharing are critical factors contributing to collaboration in infrastructure projects.

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, and 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 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 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 opinion, 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. Figure 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.

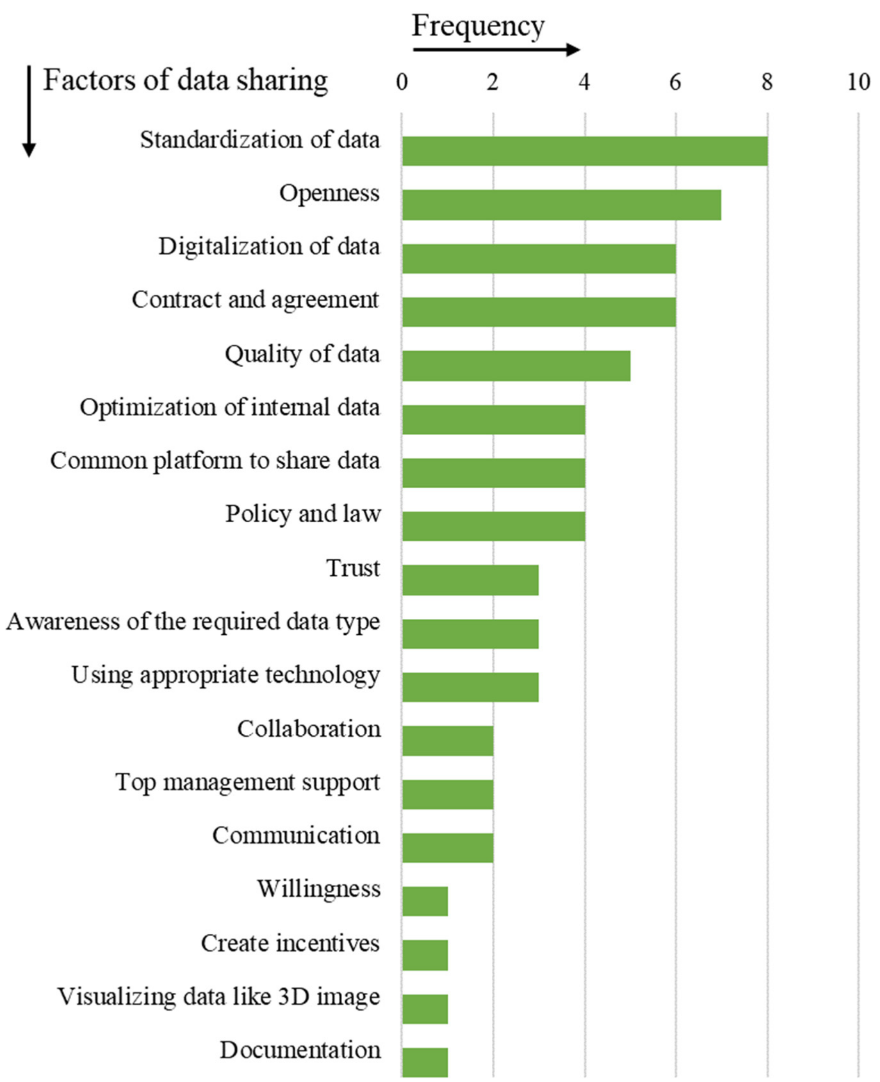

Figure 2. Factors facilitating data sharing mentioned by the respondents.

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 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 the 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 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.

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, interoperable, 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 organizations 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, and 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 the 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 1 that facilitates collaboration between various organizations, which finally contributes to data sharing in IOPs.

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 [83] 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" [84]. One of the challenges in inter-organizational infrastructure projects is the development of truly horizontal collaborative structures.

The results presented in Figure 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 that 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 [85,86]. 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 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 the development of innovative solutions. The results presented in Section 4.2 suggested that collaboration can facilitate data sharing in IOPs. Collaboration relies on win–win situations [51] 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 of IOP) and hard factors (related to the structural aspects of 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 [87], 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 [88]. The importance of trust for data sharing and collaboration has been extensively emphasized in the literature [89–91]. Trust among participants in collaboration reduces the fear of losing participants' unique values, which, subsequently, can increase the willingness for data sharing [91,92].

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.

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 multi-disciplinary 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 data, privacy concerns, restricted policies 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 also 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 and 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 their 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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