

Article

Circular Public Procurement through Integrated Contracts in the Infrastructure Sector

Sofia Lingegård ^{1,*} , Malena I. Havenvid ² and Per-Erik Eriksson ³

¹ Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, 100 44 Stockholm, Sweden

² Department of Real Estate and Construction Management, KTH Royal Institute of Technology, 100 44 Stockholm, Sweden; havenvid@kth.se

³ Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, 971 87 Luleå, Sweden; pererik.eriksson@ltu.se

* Correspondence: sofia.lingegard@abe.kth.se

Abstract: Public clients' procurement strategies are central in facilitating innovation towards sustainability. In the infrastructure sector, the three main project activities—design, production, and maintenance—are traditionally not procured in an integrated way, which results in sub-optimizations and a lack of life cycle perspective. As project actors are accustomed to traditional, non-integrated forms of contract, implementing integrated contracts imposes fundamental changes to the interdependencies among actors, resources, and activities. This study analyzes the interfaces among key project actors and the related interdependencies across design, production, and maintenance in Design–Build–Maintain contracts, and initiates a discussion on how to manage these interdependencies when implementing integrated contracts. This study of circular public procurement (CPP) focused on three infrastructure projects using integrated contracting and applied the industrial network approach (INA) to analyze interdependencies in how they may influence innovation and sustainable development. The study found significant obstacles to clients obtaining the benefits of integrated contracting and concludes that understanding interdependencies is necessary to implement integrated contracts successfully. The study contributes to the construction management literature by adapting the INA to contracting, and to the CPP literature by providing empirical evidence of sustainability and circularity in infrastructure projects.

Keywords: circular public procurement; interdependencies; integrated contracts; design–build–maintain; infrastructure projects; industrial network approach; sustainability; life cycle perspective; sustainable public procurement



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1. Introduction

Procurement policies to address ecological and social sustainability goals have been promoted through, e.g., amendments to procurement directives [1,2] in EU and OECD countries. The ambition to use public procurement as a tool to promote sustainability benefits is referred to as sustainable public procurement (SPP) [3], and is considered an essential instrument in achieving sustainability in society [4–7]. The UNEP [8] defines SPP as “a process whereby public organizations meet their needs for goods, services, works and utilities in a way that achieves value for money on a whole life cycle basis in terms of generating benefits not only to the organization, but also to society and the economy, whilst significantly reducing negative impacts on the environment”. Circular Public Procurement (CPP) additionally entails the ambition to produce products and services with an extended life span and value retention [3,6]. In this article, the term CPP will be used, as the life cycle perspective is essential to the road infrastructure sector, where sustainability and circularity approaches have great benefits due to, e.g., the large volume of materials used and the long lifetime of roads (see, e.g., [6,9]). Previous studies identify opportunities

for sustainability improvements such as the reduction of construction waste and using materials with recycled content [6,10], as well as life cycle optimizations and integrated designs that bring about synergies [9,11].

Studies on CPP in construction often focus on the tender criteria (see, e.g., [12–14]) and implementation in the client organization (see, e.g., [15–17]). Fewer studies have a focus on delivery systems where circular approaches could make sustainability improvements ([9,11]). Despite this, design, production, and maintenance are traditionally not procured in an integrated way, and thus a life cycle perspective is lacking. Instead, they are mostly outsourced as separate contracts for design, production, and maintenance over a limited time span [18].

To strengthen the possibilities for innovation, many clients have switched from Design–Bid–Build (DBB) contracts, where the contractor produces based on detailed specifications from the buyer, to Design–Build (DB) contracts, where design and production are both done by the contractor [19–22]. While numerous studies compare the effects of DB and DBB delivery systems on traditional project performance measures such as time and cost [18,19,21,23–26], there is a lack of studies on how the delivery system affects innovation and sustainable development. However, some studies of DB delivery systems suggest they may facilitate innovation, at least in terms of short-term project-level innovation [27,28]. From a more long-term perspective, some scholars argue that DB contracts may have detrimental effects on quality and life cycle costs compared to DBB contracts [29,30]. Accordingly, from a sustainability perspective, switching from DBB to DB contracts may not have the desired long-term effects.

The client's procurement and contracting strategies are central in facilitating innovation and sustainable development [31,32], though more research is needed on the types of contract that best facilitate a transition to sustainable infrastructure development [11]. The client's chosen delivery system is important, because it encourages contractors to adopt a more long-term life cycle perspective on design and production. Some scholars argue that DB contracts that integrate maintenance services (i.e., Design–Build–Maintenance (DBM) contracts) may enhance sustainability [9,11,33], but there is a lack of empirical research on whether these contracts actually do this. More research is particularly needed on the link between SPP/ CPP and contract implementation [11]. This study focuses on a client strategy for integrated contracts as a means to lower cost, innovate for sustainability, and implement DBM contracts for road infrastructure.

One of the major barriers in shifting from traditional to DBM contracting is the organizational change that it requires—both within and between separate organizations, i.e., in relationships between project actors [34,35]. Several studies use an *industrial network approach* (INA) to show the role of interdependencies in construction projects and how they affect change processes across time and space, e.g., in terms of materials [36], interorganizational relationships [37], and learning and innovation [38]. While the construction industry from this perspective is considered a loosely-coupled system [39]—i.e., projects with intense interorganizational interaction, but the 'permanent' network outside projects having less interaction—firms still make extensive interorganizational adaptations in terms of both standardization and specific adjustments. To capture the organizational change processes involved in the implementation of DBM contracts, this study adopts the INA (e.g., Håkansson et al. [40], which is suitable for identifying interdependencies between firms arising from interaction processes, and for analyzing network-like constellations of actors, resources, and activities [41,42].

When applying the INA to study the implementation of DBM contracts, the focus is on new and existing interorganizational interfaces between key actors in terms of material and immaterial interdependencies that arise when switching delivery systems. Hence, the purpose of this study was to identify and analyze key interorganizational interfaces in terms of interdependencies across design, production, and maintenance in DBM contracts. Using 26 interviews from a case study of three DBM contracts implemented by the Swedish

Transport Administration, this paper discusses how to manage interdependencies when implementing integrated contracts to achieve sustainable development.

2. Literature Review

2.1. Construction Procurement and Contracting

Traditional DBB contracts involve a separation of design and production, with the client and consultants completing the design before the contractor executes production [18,30] (see Table 1). When production is complete, the client performs a new procurement for maintenance. In Sweden, maintenance contracts often span five years, plus a two-year option if the client is satisfied with the contractor's performance. This highly separated approach requires three separate procurements for design, production, and maintenance. One advantage of DBB contracts is that an experienced client can ensure quality by specifying material and technical solutions in detail [29]. One disadvantage is that the client's design specifications reduce the contractor's opportunities for innovation, since most technical solutions are already specified. In this way, DBB contracts reduce joint problem-solving and hinder a more holistic perspective on design and production [43,44]. The separation between planning/design and production also reduces learning between actors [45] and may reduce constructability and maintainability. The absence of contractors' production and maintenance competencies during the design could also impair efficiency.

Table 1. Contract types, including content and responsible parties.

Contract Type	Contract Content	Responsible Party
Design–Bid–Build, DBB	Production	Buyer/procurer
Design–Build, DB	Design, production	Contractor
Design–Build–Maintain, DBM	Design, production, maintenance	Contractor

DB contracts improve the contractor's possibilities for innovation by allowing more freedom and an earlier involvement in the design. Son et al. [46] indicate that, by giving contractors more responsibility early in the design process, they can use their knowledge of materials and other resources to reduce pollution and other environmental impacts. However, when DB contracts are procured based on traditional competitive tendering on price, the contractor has no incentive to spend time and money on development activities [47]. Furthermore, the contractor does not have any incentive to improve quality or reduce life cycle costs. To minimize the risk of exceeding time and budget frames, production is instead based on trusted solutions and existing knowledge.

Switching the delivery system from DBB to DBM involves a major change for all actors, their activities, and their need for resources and competencies [33]. When procuring integrated DBM contracts, contractors are involved throughout the project, being responsible for design activities, production, as well as maintenance (ibid) (see Table 1). This type of procurement adds a life cycle approach by integrating the three main activities in the life cycle of infrastructure, thereby providing a possibility for balancing construction and maintenance solutions from cost and material loop perspectives [9,11].

CPP is defined by Alhola et al. [6] as "a procurement of competitively priced products, services, or systems that lead to extended life spans, value retention, and/or remarkably improved and nonrisky cycling of biological or technical materials, making use of and supporting the circular business models and related networks". While SPP mostly focuses on product and technology, CPP adds a focus on the complex network of supply chains and other stakeholders [6,48,49]. It is about being "part of a system that promotes circularity instead of closing the material loop itself" [6]. Other studies argue that there are many similarities and that the concepts can be evaluated as a whole, e.g., [3]. In this paper, the term CPP will be used, as the life cycle perspective plays an essential role in DBM contracts. However, the literature regarding SPP will also be included in this term. Currently, few criteria have focused on the actual circular life cycle approach [6], but on criteria connected

to products, materials, and the recycling of materials [6,10,13]. DBM contracts add a life cycle perspective to the facilities in the construction industry and to the practice of CPP.

The life cycle perspective and the integration of the phases in the life cycle of the infrastructure can improve relations between the actors, but they also struggle with the links between these phases, such as including more than one life cycle phase in the contracts, integrating both construction and maintenance aspects in the design and dealing with rigid and specific procurement specifications limiting the design [9,11]. This creates knowledge silos, mostly in the client organizations, which are a weakness in the implementation that could be mitigated by better training [3,50,51]. It is essential to involve practitioners beyond experts, in the transition towards circular procurement to facilitate implementation and create awareness [3,52,53]. For CPP in the construction sector, knowledge in design, specification, and site management are essential to reduce waste and find appropriate products and materials [6]. Collaboration between actors is necessary to identify and explore CPP [10]—especially since lack of knowledge and awareness, as well as resistance to change are key obstacles to the implementation of CPP [3,5,50,51,53]. This may promote knowledge sharing between actors across project activities, resulting in improved constructability and maintainability. Knowledge of how the finished infrastructure works during maintenance can also be given to the actors responsible for design and production, which may lead to better design of future products and increased efficiency [54]. Integrated DBM contracts are a way for the client to strengthen the contractor's incentives to improve quality and reduce life cycle costs during maintenance, instead of merely reducing short-term investment costs [55,56]. Integrated contracts also incentivize innovation as costs related to innovation do not have to be paid back during production, but during the longer maintenance period. Several governmental reports in Sweden suggest that integrated contracts may indeed improve public clients' innovation capabilities [57,58]. While there is little research on DBM contracts, there is also a lack of research studying the effects of CPP from a life cycle perspective in the construction sector. Additionally, the change to CPP and DBM contracts may not have the desired effects, and this is an issue that is further discussed later in the article. This is the starting point of the present study, investigating the implementation of DBM contracts in terms of handling past, present, and future interdependencies in an interorganizational setting.

2.2. The Industrial Network Approach as an Analytical Approach

The INA has demonstrated that, contrary to traditional purchasing and marketing theories, industrial firms operate in quite stable business markets [59,60]. Rather than entering and exiting different markets with ease, firms base much of their operations on a set of established business relationships. The empirical insights into the central importance of firms handling a variety of business relationships, on both the buying and selling side of their business, have resulted in the theoretical and methodological development of how to study the interaction taking place between organizations and the various social, organizational, and technical adaptations that follow [61].

A central observation in studies adopting the INA is that interacting parties engage in various adaptations over time [59]. Interaction takes place at the interface between firms and, as they adapt to each other, the interfaces also change [42,62]. The ARA model (Actors-Resources-Activities) is based on observations of how the adaptations made between interacting parties change not only the parties themselves, but also the nature of their relationship or the interface between them. As such, the ARA model focuses on the dynamics of interorganizational interfaces [41]. The model outlines three layers of business relationships that connect the internal operations of the firm with those of other firms: the *activity* layer, the *resource* layer, and the *actor* layer. These layers reflect adaptations taking place at the interface between firms and represent interdependencies that have formed over time. The adaptation of activities can be the way in which the production of a supplier adapts to the transportation of a customer. Adaptation of resources may be the way in which a supplier's components are adapted to the product of a customer, and

the way in which mutual learning results. Finally, adaptation in the actor layer may be the way in which these firms develop social sentiments and learn about each other, i.e., by communicating in their daily operations and planning for the future.

These interorganizational adaptations affect the interdependency between parties in terms of representing mutual investments over time in organizing essential operations [63]. The adaptations represent interorganizational learning, routines, and practices [40,64,65]. However, while adaptation makes interfirm operations more efficient, it also creates tensions that may both drive and hinder change in relationships [66]. Another key feature of interaction reflected in the ARA model is that it takes place within a network context, which means that changes in one interface (relationship) affect other interfaces.

In this paper, the ARA model is used to investigate how new ways of contracting can be implemented in construction projects consisting of both established and new relationships, i.e., interfaces that entail specific interdependencies. The following section details the analytical framework connecting the ARA model to different forms of contracting.

2.3. Analytical Framework: An Industrial Network Approach to Analyze Integrated Contracting

Design, production, and maintenance are interdependent and affect each other in two ways. First, the design affects what can be built and how, and how the final construction can be operated and maintained. Likewise, how production and problem-solving are done during the production process affects maintainability. Secondly, there are interdependencies that are reversed in time, which means that planned production and maintenance activities may affect how the design and production activities are carried out. For instance, by using experience and knowledge about production and maintenance, e.g., through people or documentation, these types of activities can directly affect the design process and its outcome. There are thus two forms of interdependency between these three activities, i.e., those that cause effects due to their natural sequence in time, and those that cause effects due to the involvement of ideas, solutions, documents, and/or people that are related to future activities. These two forms of interdependency are illustrated in Figure 1.

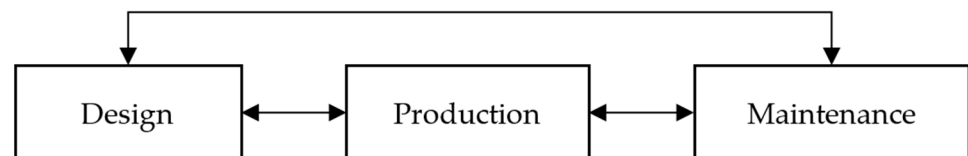


Figure 1. How design, production, and maintenance are related as types of project activity.

In a construction project, design, production, and maintenance activities are carried out sequentially or in parallel. These activities, which involve a number of sub-activities, require a set of actors and resources. From an INA perspective, actors become accustomed to a particular way of working with each other, i.e., they make specific adaptations [67]. Using the ARA model, such adaptations can be seen in the three relationship layers, i.e., actor, activity and resource layers [63]. Adaptation in the actor layer refers to how individuals and organizations learn how to interact and adopt particular roles and responsibilities in relation to each other. The activity layer refers to how particular activities are adjusted in relation to each other to smoothen various processes. Finally, the resource layer refers to how resources are pooled to form resource combinations that achieve the desired project outcome. Resources may be either material or immaterial, where competencies and relationships are examples of the latter, and physical components and tools are examples of the former (ibid). The two forms of time interdependency—those that exist because of a natural sequence in time and those that can be stated to be reversed in time—will be shaped by such adaptations. Put differently, how the two forms of interdependency play out in a specific project and what consequences they create for the actors are a result of specific adaptations prior to and during the project.

3. Method

3.1. Case Selection and Description

A case study approach is the preferred research method when seeking to understand complex phenomena [68,69]. Therefore, a single case study methodology was chosen for this study to examine DBM implementation in the infrastructure sector. This method allows for context and exploration while also telling a story [70]. This paper is based on a case study of three integrated contracts procured by the Swedish Transport Administration (STA).

The STA procures infrastructure (design, production, and maintenance) within the scope of the Public Procurement Act (LOU) [71], which is based on EU directives on public procurement that are similar across member states. The focus is on non-discriminatory treatment of suppliers and transparency of the procurement process [72].

Traditionally, the STA has procured most of its projects through DBB contracts, but to facilitate more long-term sustainable development, it has recently procured three projects through DBM contracts—the only large-scale DBM infrastructure projects in Sweden. To gain optimal insight into this phenomenon, this case study examines all three projects.

The three projects (see Table 2) include the design, production, and maintenance of a new road that, at the time of data collection, had been handed over to maintenance. When these three contracts were procured by STA, the use of functional requirements in Design–Build (DB) contracts was a new feature to which some of the actors were not accustomed.

Table 2. Presentation of the three projects.

	Project A: Norrorts-Leden	Project B: E4 Sundsvall	Project C: Riksväg 50 Motala-Mjölby
Content	New road (6 km) and tunnel (1 km).	New road (17 km) and bridges (25).	New road (28 km) and bridges (39 small, 1 large).
Cost	SEK 725 million (~EUR 70 million), whereof maintenance 20%.	SEK 1.1 billion (~EUR 130 million), whereof maintenance 7%.	SEK 1.2 billion (~EUR 120 million), whereof maintenance 10%.
Time frame	Design and production: 2005–2008 Maintenance: 2008–2023	Design and production: 2010–2014 Maintenance: 2014–2034	Design and production: 2010–2013 Maintenance: 2013–2033

Project A (Norrortsleden) was the STA's first DBM contract and was a larger road connecting two major highways. The project was procured with a fixed price and yearly payments for maintenance. Despite initial perceptions of increased freedom compared to traditional contracts, the contract included over 600 requirements, which left little room for the contractor to choose technical solutions.

Project B (E4 Sundsvall) was a rural project, which made the client think there would be significant flexibility in technical solutions. However, the margin for the location of the road was only 30 cm. The project was procured using a fixed price and the tender evaluation was focused on the lowest price.

Project C (Riksväg 50 Motala-Mjölby) entailed a smaller road than in projects A and B. The contract was based on a fixed price, divided into production and maintenance. There was a bonus for each week, up to 8 weeks—for early completion. The length of the contract was decided by several experts and personnel, including some from Project B.

3.2. Data Collection

Interviews are a highly efficient method for gathering detailed empirical data [73], and semi-structured interviews are accepted as the core of good qualitative research [74]. In this study, a total of 26 semi-structured interviews were conducted from 2016 to 2017. This time frame of data collection was considered suitable, because the maintenance phase had been underway for at least two years in all three contracts, which meant that maintenance had gone through at least two seasonal cycles and thus could be evaluated. The respondents included three different types of actor, i.e., clients, contractors, and design consultants, who represented different types of activity, i.e., planning/design, production, and maintenance.

An interview guide was used to capture interdependencies across design, production, and maintenance, so that the main topics about integrated contracts were defined while leaving room for follow-up questions if needed. Project documentation was used to complement and confirm the information from the interviews. By using several sources of information, triangulation was made possible [75].

3.3. Data Processing and Analysis of Findings

This study took an abductive approach [39], which means that the data collection, processing, and analysis were the result of iteratively combining theoretical and empirical insights during the research process. For example, it was not until after data collection that the relevance of using the INA was realized. As addressed in Section 2.3, this led to a conceptualization of DMB contracts based on the INA. Subsequently, on the basis of the ARA model, the concepts of interorganizational interfaces and interdependencies were used to process and analyze the data. In this study, the term *interorganizational interfaces* relates to the relationships between the client project organization and the contractor maintenance organization (each of which is reviewed in the results section). The concepts of interorganizational interaction, interfaces, and interdependencies are interrelated; interorganizational interaction takes place at the interface between organizations, i.e., different actors that form interdependencies through their resources and activities. These interdependencies affect how actors relate to each other, i.e., the interface between them. There are interdependencies that exist because of specific adaptations made by actors, and those that actors have to manage despite having made adaptations or not, such those affecting possibilities for action.

First- and second-order analyses were performed to process the data [74]. The first-order analysis was to search for empirical patterns indicative of interdependencies among actors, resources and activities. This analysis revealed empirical accounts of different activities and how they were interlinked, or where links should have been made to promote the intended outcome of the contracts. This resulted in activities being the primary analytical construct around which the results were structured, with actors and resources being secondary analytical constructs. The second-order analysis searched for underlying reasons why particular links were there, why they were difficult to break or change, and why some new links were difficult to establish. The same analysis was done for resources and actors, although they were sometimes more difficult to trace in the data material. As both the first-order and second-order analyses were based on an industrial network approach—more specifically on the concepts of interfaces and interdependencies—a coherent logic was identified between the presence and absence of links between activities, resources, and actors, and the difficulties of establishing and changing interdependencies.

The studied projects consisted of five main actors: the client's project organization (client PO, managing both design and production), the client's maintenance organization (client MO), the contractor's project organization (contractor PO, managing both design and production), the contractor's maintenance organization (contractor MO), and the consultant's design organization (consultant DO), see Table 3. The project and maintenance organizations of the contractor and the client were financially separated in terms of having their own profit centers. Therefore, in this study, they were treated as different actors although they were part of the same organization.

Table 3. Participating actors and their abbreviations used in the text.

Participating Actors	Abbreviations
The client's project organization, managing both design and production	client PO
The client's maintenance organization	client MO
The contractor's project organization, managing both design and production	contractor PO
The contractor's maintenance organization	contractor MO
The consultant's design organization	consultant DO

When implementing a DBM contract in a constellation of actors accustomed to a particular organization of activities and resources, reorganization is required. The adaptations that have taken place form interdependencies that may need to change and some new ones will need to be established for the contract to work as intended. In the results section, the findings from the analysis of the three DBM contracts are structured according to the two forms of time interdependency between design–production, design–maintenance, and production–maintenance. There is also a systematic review of the interorganizational interfaces between the key actors in terms of the interdependencies affecting the project outcomes. The interdependencies relating to design and production are addressed through the interfaces between contractor PO and consultant DO, and between client PO and contractor PO. The interdependencies relating to design and maintenance are addressed through the interfaces between client PO and client MO, and between contractor PO and contractor MO. The interdependencies relating to production and maintenance are addressed through the interfaces between client MO and contractor MO, between contractor PO and contractor MO, and between contractor PO and client MO.

4. Results

In this section, the interdependencies between design and production, production and maintenance, and design and maintenance are described. The actors involved in the three studied projects are shown in Figure 2.

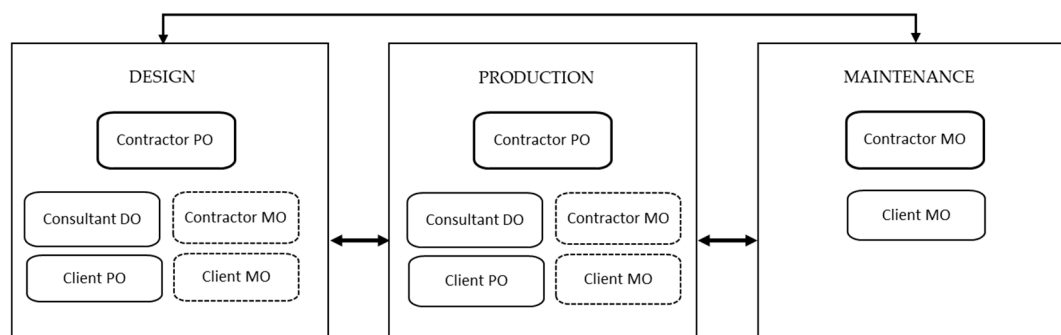


Figure 2. The actors involved in each phase of the projects. The actors indicated with thick outline had responsibility for each phase, while the dotted outlines indicate less-involved actors.

4.1. Interdependencies between Design and Production

4.1.1. The Interface between Contractor PO and Consultant DO

Under the DBM contract, the design consultant was contracted to perform design in close collaboration with the contractor. This was a new interorganizational interface because, in traditional DBB contracts, the client contracts a design consultant to manage the design. Design-related competence is normally not a resource that contractors have in-house, thus in all three projects, the contractors used design consultants, and all contractors were content with the consultants' work. In projects A and C, the contractor had a design manager in-house overseeing the design process. In Project B, however, the design manager was part of the design consultant's organization. While the contractor was satisfied with the design work, the consultant worked independently, which suggests there was less interaction than anticipated. However, the consultant was on-site two days a week to assist close collaboration, which meant the contractor and the consultant were able to find better and quicker solutions.

Even though contractors A and B had different approaches to design management (in-house or not), they both had challenges working with their design consultants and had to establish new ways of working. In Project A, the collaboration between the contractor and the consultant was initially problematic as the consultant was working in a traditional way as if it was working for the client. A similar situation arose in Project B, where the consultant felt pressured to deliver cost-saving solutions for the contractor while maintaining a good

relationship with the client, since it would go back to working for the client after the project. In addition, the consultant and the client already had a long and close business relationship.

In Project C, however, the contractor had project management and design management in-house and on-site: “We controlled our consultants directly and used our production experience to achieve a good technical solution that was adapted for production” (project manager, Contractor C). However, the design consultant was not located on-site, which became problematic as small adjustments needed to be made regularly. Furthermore, according to Contractor C, the quality of the design suffered because the consultant was not on-site and only used pictures and measurements as a basis for the design. However, the fact that the contractor had on-site management for design and project management still made it possible to integrate design and production.

4.1.2. The Interface between Client PO and Contractor PO

Because the contractor takes over the responsibility for design in DBM contracts, the roles of the client and contractor needed to change significantly in the studied projects. In Project A, the collaboration between the client and the contractor was intense, with the client holding regular meetings where important design information was provided to the consultant and contractor. While the client could not decide what solutions to choose, it could relate its experiences of certain solutions’ quality and robustness. The client’s project director in Project A explained: “Even though the contractor was entirely responsible, we had decided that our specialists and project management should support them. Even if we leave the responsibility [to the contractor], we can still, for example, explain further how we have thought about the functional requirements, so there were no closed doors”. The contractor appreciated this support and suggested that the client engage itself more in design in DBM projects. Both parties were content with the collaboration, which ultimately facilitated the interdependency between design and production.

In Project B, the opinions of the contractor and the client diverged about the collaboration. While the client’s project manager described it as ‘good’, the contractor’s assistant project manager thought the geographical distance between the offices was a problem; the distance and less frequent interaction meant it took time to establish a good way of working together. The contractor also had difficulties coordinating the different new roles within its own organization: “We understood our own roles and what to do, but no one else understood them” (project manager, Contractor B). If the contractor organization had internal uncertainties regarding roles and responsibilities, this likely also affected its collaboration with the client.

In the beginning of Project C, the client and contractor each had a collaboration facilitator, and shared goals and a common vision were set early on. Both client and contractor believed the collaboration worked well because of this, but also emphasized the importance of particular individuals in the project: “Everything is based on the people in the project. You can make it work if you want to” (project manager, the client, Project C). The client also made an effort to mirror the contractor’s organization to create a smoother process and a greater capacity to collaborate.

The production started earlier compared to a traditional contract, which resulted in some issues. In Project B, for example, both contractor and client described the production start as a bit hasty and thought more time should have been given to the design first. The contractor was working under time pressure, and thus started excavating before the design was complete, which resulted in work needing to be redone. Moreover, payment from the client was not scheduled to start until production started, which was another incentive to shorten the design process. This could be considered problematic in a project where the same actor was contracted for both design and construction, which was the case in the DBM projects. The contractor stated that a less rushed process would have allowed more time to communicate ideas to the client in a better way: “For many parts of the production, the design was only a day ahead of the production start, resulting in a constant pressure to provide thumbs up or not” (assistant manager, the client, Project B).

A major issue for all three projects was the client's inexperience of working in DBM contracts and lacking the management skills required. For instance, in Project B, the approval of the design took so long that the contractor started production without the client's consent, which in turn resulted in further delays as the contractor had to start over several times. The contractor's project manager thought the client hesitated to make decisions due to inexperienced staff and excessive control from top management, which sometimes led to a situation where no one was making any decisions.

Similar challenges occurred in Project C, where the client's design manager found it challenging to provide feedback for the project while safeguarding the client's interests, and this resulted in additional work during production. Moreover, the client expected smaller batches of design documents to arrive continuously from the contractor, but they arrived sporadically in large clusters. Project C also failed to establish a process for design approval and used a trial and error approach. The client's design manager did not audit all the documents but reviewed how the contractor had interpreted the requirements and provided corrections if possible. Eventually, this process was improved, but initially, the client did not have the necessary experience or knowledge.

4.2. Interdependencies between Design and Maintenance

The Interfaces between Client PO and MO, and between Contractor PO and MO

All three projects had similar challenges related to maintenance in the design process, which applied to both the contractor and the client. Traditionally, design and maintenance are contracted separately; hence, integrating the two represents significant organizational change. In Project A, the client and the contractor tried unsuccessfully to involve their maintenance organizations in the design process. It failed mainly because of the contractor MO's inexperience with DBM contracts and lack of capacity to engage in the design process. However, the client was very pleased with the final product and the contractor's project manager exemplified the life cycle perspective in the choice of coating: "It is a higher quality coating than we would have chosen if it had been a traditional contract. We spent more resources and money on making a higher quality coating to save time and costs during our 15 years [of maintenance]". Another aspect of the contract that fostered the life cycle perspective was the penalties for closing the road for maintenance work, which meant the design process focused more on achieving higher quality to minimize maintenance. The client MO, however, did not see the point of engaging in the design process when its maintenance commitment was years away. It was opposed to the whole DBM concept and was reluctant to participate since the contractor would manage the maintenance.

The contractor's project manager in Project B described an internal silo structure and 'watertight bulkheads' between the PO (including both design and production) and the MO. Attempts to involve the MO failed due to a lack of clear roles and knowledge. The consultant DO had a similar impression and did not recall an actual focus on maintenance issues during the design process. The maintenance personnel were invited to meetings, but these meetings ended as they did not contribute. The contractor MO did, however, participate in the tender preparation more than usual—providing prices for parts and giving tips on establishing a good work environment. However, both the client and contractor thought that the maintenance perspective in the design was lacking. According to the client, only the client MO contributed to the design. The client's maintenance manager was included to some extent in the process, since he was fortunately also responsible for the maintenance areas surrounding the site.

In Project C, there were similar problems involving both contractor and client MOs. The production team was involved in the design to ensure buildability, but against the wishes of the PO, the maintenance team did not participate in the design process. Some adjustments to facilitate maintenance were made, but nonetheless, the MO did not have any interest in participating as maintenance was not scheduled to start until four years later.

4.3. Interdependencies between Production and Maintenance

The Interfaces between Client and Contractor MOs, between Contractor PO and MO, and between Contractor PO and Client MO

With a DBM contract, the same contractor is in charge of both production and maintenance, which accentuates the interdependency between these activities. Maintenance is affected by the technical solutions chosen in the design process and how they are executed during production. Technical documentation from the design and production processes is needed to perform maintenance, and documentation needs to be in place between client and contractor, because, while the client owns the road, the contractor is responsible for maintaining it. This new type of relationship between client and contractor created confusion in all three projects, and the long maintenance period created challenges, because the format of the information needed was not specified. In Project B, the contractor even argued that the client would not need the documentation until the end of the contract, which was 20 years later. The client, however, wanted the documentation when the facility was transferred from production to maintenance, but the lack of adequately established routines made the handover to maintenance difficult. Furthermore, since there was uncertainty regarding the timing and type of documentation, neither client nor contractor had a clear strategy for how to handle it, and decided either to handle it in the traditional way, or not at all.

Involving both the client and contractor MOs in the design process also affects production. This caused some problems during the handover of Project A due to a reluctance to engage with the client MO, as explained previously. It also resulted in an inefficient handover process in Project B since the client MO was not prepared. However, in Project C, the handover process was realized without difficulty due to good planning and dedicated personnel. The client MO was ready and capable of receiving the facility, and the contractor PO was already used to working with the client MO. In this project, the handover was described as “fast, smooth and efficient” both by contractor and client. Adequate planning, dedicated personnel, and handover coordinators on both the contractor and client sides also facilitated the process. The fact that the contractor was already maintaining the surrounding area was described as “fortunate and necessary” by the contractor, since the maintenance contract of Project C simply would have been unprofitable to manage on its own. This was supported by the client’s maintenance manager, who stated it was essential that the contractor won this maintenance contract due to economies of scale.

In Project B, the contractor also maintained the surrounding area, which provided both contractor and client with some advantages. The involvement of the client’s maintenance manager in the project was a great advantage for the client, since he was well informed about the project and had an established relationship with the contractor’s MO. However, compared to the smooth process of Project C, the handover journey for Project B was completely different. Even though the client’s maintenance manager had insight into the project, the rest of the client MO’s personnel had not been involved, which caused problems in the handover as they did not understand the difficulties involved in taking over a project of this magnitude. Furthermore, the contractor thought the client had been unclear regarding the type of documentation needed for the handover to maintenance, which prolonged the process. Additionally, the contractor did not receive adequate information about the maintenance documentation, which suggested a lack of coordination between the production and maintenance processes.

In Project A, the client MO was not satisfied with the use of DBM as it did not have any insight into the maintenance procedures of the contractor, who had subcontracted the operational part of the maintenance (e.g., snow clearing and mowing) to the firm already maintaining the surrounding area. Although the technical systems in the tunnel required more maintenance than a normal road, the 7-km stretch of road was too short to obtain any economies of scale. This was highlighted by the contractor’s project manager: “From a maintenance perspective, 7 km is very short. It’s nothing that you can build an organization and a business around. In order to get more efficient maintenance work, you need larger

objects, so you may want to add a maintenance area in connection with such a project to get a larger volume". A similar solution was found in Project C, where the contractor had also subcontracted the operational tasks of maintenance.

Another challenge of the maintenance activity in DBM contracts is the long-term perspective. The client's maintenance manager in Project B described the difficulty in setting maintenance requirements for 20 years. While the terms of the surrounding maintenance contracts change over time, the requirements for the DBM contracts would stay the same as when the contract was procured. "This would imply driving on a road of a great standard and then suddenly entering an area where the standard is poor, followed by the same great standard", said the client's project manager, describing the quality patchwork created by different requirements. Therefore, the contract in Project B will be renegotiated continuously and the project manager believed that most of the initial requirements for maintenance would change during the contract period. This implies that continuous collaboration between client and contractor MOs is important for this to work well.

A completely different approach was adopted in Project A, where the client did not have to pay for upgrades to the road due to a strategic decision by the MO. Therefore, the road will require heavy reinvestment when the contract ends, e.g., IT systems in the tunnel. This is the same MO that was reluctant to adopt the DBM contract in the first place. For Project C, now a few years in, the requirements in the maintenance contract have already changed somewhat, which has resulted in the DBM harmonizing better with the new requirements on the surrounding roads. The client has paid for a few upgrades during this time to increase safety. "Thinking back 20 years, a lot has changed—everything really" (contractor's maintenance manager). All the changes that will be needed during the contract period are related to extra costs for the client, who owns the road. Even though the contractor is responsible for maintenance, the client still plans to make inspections and follow up the requirements regularly.

5. Discussion

This study provides several important insights regarding how interdependencies affect, and are affected by, the implementation of integrated contracts. The case involves project settings where the actors were accustomed to other forms of contract and faced the challenge of changing their existing social interaction patterns (the actor layer), mutually adapted activities (the activity layer), and key resource combinations (the resource layer) developed over numerous projects. In this section, the interfaces identified in the study and the interdependencies of those interfaces are discussed.

5.1. Discussions of Specific Interfaces

In the interdependencies of design and production, the two examined interfaces were those between contractor PO and consultant DO, and between client PO and contractor PO. In regard to the former, it was clear that, in Project A and Project B, the already established relationships between client POs and consultant DOs hindered the consultant and contractor in identifying new ways of relating to each other, despite the fact that the consultants were hired by the contractors. Thus, even though there was a contract stating which two actors should be interacting, the way resources and activities were usually organized obstructed a new coordination mode between the contractors and the design consultants. Thus, reactivating formerly established activity links and resource combinations was considered more efficient than establishing new ones. In addition, the established relationships between the clients and design consultants were developed over time, and expectations of how the relationships were to be reactivated in subsequent projects were managed through 'traditional' contracts. In Project C, another issue was the lack of co-location of key resources and activities connected to contractor and design consultant, which initially hindered coordination of activities and resources, as well as the establishment of a social relationship to facilitate communication. Additionally, the contractor did not have an in-house design manager, thus the DO took this role instead,

which undermined the role of the contractor as the owner of the process. The consequence was a lack of efficiency and potentially poorer design quality.

In the interface between client PO and contractor PO, all three projects had unsuccessful and successful attempts of the two organizations to establish new roles and responsibilities in relation to each other. Although all three projects displayed more or less successful attempts at achieving collaboration, they all had difficulties in establishing efficient routines for design approval, which clearly affected parallel and subsequent production activities. The inexperience of the client in being a counterpart not in full control appears to have been a principal challenge, which was due to an existing internal organization of activities and resources not adapted to integrated contracts. This could be seen in Project B, where both the contractor and client struggled to find efficient coordination of activity links and resource combinations across design and production, which ultimately caused production delays. A factor that reinforced these difficulties was the payment method by the client, which was adapted to traditional contracting and created little or no incentive for the contractor to prolong the design process. In Project A, the advisory meetings in which the client provided the consultant and contractor with important design information were perceived as very beneficial by all parties. In Project C, establishing shared visions and goals early on, and appointing managers to facilitate new relationships, helped smooth collaboration to some degree. However, it did not eliminate all problems and contractor and client still experienced difficulties in coordinating design and production.

Regarding the interdependencies between design and maintenance, the two interfaces examined were between the project and maintenance organizations (PO–MO) of the client and contractor respectively. Although the PO and MO were within the same main organization of the client and contractor respectively, they were treated as separate actors in this study as they had their own profit centers. The most striking result across all three projects displayed in the relationships between client PO and MO, and between the contractor PO and MO, was the difficulty of involving the maintenance organizations in the design process. Even though the contractor MOs would handle the long maintenance contracts, they found it difficult to establish an effective way of participating, had no clear role in the process, and lacked the competence to contribute. In addition, there were no established relationships in the sense of having adapted to one another in the past. The client MOs that were to take over the maintenance once the contractor maintenance contract ran out, found it unnecessary to engage their resources in the project several years before their responsibility was due to start. There was thus both the issue of lack of resources as well as the timing in engaging them. To function as intended, integrated contracts demanded early engagement of resources that traditionally were not activated until much later. In turn, this meant that it was not only an issue of *which* resources needed to be available, but also *when*.

In the interdependencies between production and maintenance, the interface between the contractor PO and MO was once again central, but also the ‘mixed’ interfaces of client MO and contractor MO, and contractor PO and client MO. In projects A and B, the relationships between the contractor PO and client MO showed clear effects of the client MOs not having been involved earlier in the projects, as well as the lack of established routines of the contractor POs concerning which documentation was needed for the handover and when. This was less of a problem in Project C, as the area to be maintained by the client MO was just an addition to its existing maintenance work in the area. Thus, not committing resources early on in the project could potentially be compensated for by already having resources and activities activated on the site.

Further, the results of the study show that the relationships between the client MOs and contractor MOs were highly influenced by whether the client was to pay for any changes made to the contract over time. The coordination between the two actors seemed to be facilitated if the client was to pay for changes or upgrades (e.g., IT investments), which allowed for changes to the resources and activities needed over time. Lastly, in the relationships between the contractor PO and the contractor MO, the ease of handover was dependent on creating economies of scale for the contractor MO. In all three projects, the

contractor had the surrounding maintenance contract when the DBM contracts went into the maintenance phase, which enabled the contractor MOs to use their existing resources for the additional facility. However, in Project A, the contractor MOs lost the surrounding maintenance contracts during the maintenance phase, which left no opportunity for economies of scale. In this case, the maintenance was subcontracted to a third party.

5.2. Overall Discussion of Interdependencies among Interfaces

While DBM contracts promote the idea that there should be a single point of responsibility for design, production, and maintenance, this study shows that this single point of responsibility entails a number of different interorganizational interfaces that need to combine for the contract to work.

Across these interdependent interfaces, there are different actors with their own 'logics' of how to create benefits from linking activities and combining resources. These interfaces are referred to as 'contact points' [62] and each has a role to play in delivering the different elements of the contract, albeit with different incentives to accrue benefits from it. In the study, different actors were represented both by different internal units within the same organizations (e.g., client PO and client MO) and by different organizations (e.g., consultant DO and contractor PO) that, over time, had adapted their activities and resources to their respective contexts. They did so without needing to take each other's contexts into extensive consideration, so there was little or no adaptation of activities and resources to facilitate the way they related to each other within a DBM contract, nor there was any history of social interaction through which the actors, at both the organizational and individual levels, had become acquainted within the framework of such a contract.

The absence of social interaction left little incentive to develop any formal or informal routines regarding how and when to communicate, how to reach an agreement on which documentation was needed and when, and the format in which it should be provided. Rather, the socialization processes and adaptation of activities and resources that had taken place in the past were within the framework of traditional contracts (e.g., DBB). As such, the familiar formal and informal routines had developed on the basis of a different form of contract. These routines were based on the actors having particular roles and responsibilities in relation to each other. The 'traditional' interfaces represented a specific way of relating and adapting to each other, which made perfect sense from an efficiency point of view. However, working under a DBM contract, these interfaces ceased to make as much sense. Some interfaces became obsolete in that they no longer played the same role (e.g., between client and design consultant) and needed to change, and some needed to be established from scratch (e.g., between contractor PO and contractor MO). As seen in the case study, this was difficult during the course of single projects where all actors were unfamiliar with the new way of working—especially as the client had little experience of its new role and responsibilities. This created tension between established interdependencies and the need for new ones. Established interdependencies in the way the actors' activities and resources had been interrelated (or not) in the past affected which new interdependencies could be established, how effective they were, and the difficulty of establishing them.

6. Conclusions

This paper contributes to the area of sustainable public procurement by providing empirical findings on the implementation of a life cycle perspective to infrastructure projects, i.e., CPP. The main difference between DBM contracts and traditional contracts (DBB and DB) is the life cycle perspective and the inclusion of the maintenance phase in the contract. The main focus of this study is the implementation of CPP through DBM contracts in the projects, while previous studies of CPP in construction have an emphasis on the tender criteria [12–14] and implementation in the client organization [15–17]. In addition, the concept of CPP includes the network of supply chains and other stakeholders, with the aim of achieving, e.g., extended life spans and value retention in products, services or systems [5,6]. It can therefore be argued that, with DBM contracts, the infrastructure

sector has entered CPP. This makes sense considering that circular public procurement is switching from price per product unit to price per delivered service [6,48], which is the case with DBM, where functional requirements focusing on results are used instead of traditional detailed requirements. This study helps to address the lack of empirical evidence of sustainability and circularity in the public procurement process [3,6] by investigating implemented contracts that integrate the life cycle of the infrastructure. Furthermore, the study points to the difficulties in implementing circular approaches all the way down to the project level. In the studied case, decisions on CPP and the use of the DBM contracts were made at the top management level. Even though implementing DBM requires a significant change in mindset and operation, many things were addressed in a traditional way, e.g., delaying payment until the construction started (which hindered an engaged design process) and focusing on production while maintenance was partly overlooked, thus compromising the life cycle approach.

Previous research on construction contracting mostly focuses on time and cost performance in DBB and DB contracts [18,20–22]. However, by focusing solely on DBM contracts and emphasizing sustainability aspects, the findings of this study contribute to research on the role of the client in initiating and facilitating sustainable development. Although the scant prior research on DBM contracts indicates that the integration of design, production, and maintenance activities into one contract may have potential long-term performance benefits [9,11,33], the findings of this study identify significant integration challenges in obtaining these benefits. The challenges encountered in this study align with some of the problems identified in previous studies, such as lack of knowledge and awareness in regard to CPP and the life cycle perspective it brings [11], and the importance of collaboration between actors [76]. As such, this study provides insights on contracting and managing the integration of design, production, and maintenance for both improved performance and sustainability.

In addition, this study contributes to the construction management literature by adopting an industrial network approach (INA) to contracting. With the ARA model as an analytical basis, the findings show that it is not enough to integrate the three main activities of design, production, and maintenance on a contractual level, since this does not automatically imply an immediate integration of actors, resources, and activities. Interdependencies need to be considered in the required change processes towards increased sustainability [77] and sustainable public procurement. As such, the INA is helpful in illustrating how the integration of actors, resources, and activities matters when attempting to integrate design, production, and maintenance in DBM contracts. This study demonstrates that, in order to achieve efficient coordination of key actors, resources, and activities, these elements need to be available and activated at appropriate times. The degree to which this is possible and the degree of willingness among actors to achieve this are based on past, present, and planned interactions. Ultimately, the findings result in five recommendations, or management tasks, on how to handle interdependencies that affect the integration of actors, resources, and activities in integrated contracts:

- *Identifying traditional ways of interrelating is important for the sake of breaking existing routines and ways of operating.* The lack of needed relationships for the integration of the actors in design, production, and maintenance may result in reactivation of formerly established relationships, activity links, and resource combinations applied in non-integrated (i.e., traditional) contracts. Such reactivation hinders the integration needed for a satisfactory implementation of DBM contracts.
- *Identifying and implementing new ways of organizing actors, resources, and activities is important to initiate integration.* In the absence of established relationships for integration, coordination of activities (e.g., through advisory meetings, co-location, etc.), and resource combinations across design, production, and maintenance become an essential management task in integrated contracts.
- *Acknowledging the need for resource development (e.g., competence development in certain areas) is important for the realization of integration.* Establishing new relationships and

routines explicates the lack of resources among established actors and the activities they normally perform. Therefore, in the implementation of integrated contracts, project actors need to be open to change.

- *Identifying the proper timing of resource combinations (e.g., maintenance and production competence) is important for the integration process.* Integration requires particular resources to be available and combined at particular points in time, which differs from traditional contracts.
- *Creating knowledge and awareness of CPP and understanding the diverse ways in which project actors (e.g., buyers and contractors) create benefits from implementing integrated contracts is important for actors to be incentivized to initiate innovation and sustainability from both short and long-term perspectives.*

This paper is a first attempt at using a network perspective to explicate the challenges of transitioning to sustainable public procurement through integrated contracts. Additional empirical studies—preferably longitudinal case studies—that capture projects in their entirety, including long-term maintenance, would be beneficial. In this study, a network perspective has been helpful in explicating the interdependencies of past, present, and planned interaction among project actors, and has proven essential in understanding how to transition to integrated contracts and manage through them. Additional studies on integrated contracts applying interorganizational and/or network perspectives would assist in confirming and complementing the findings of this study.

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