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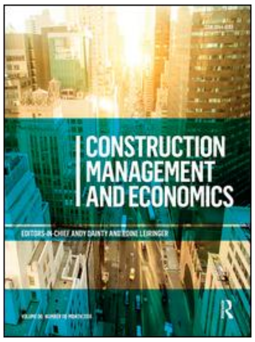
Citation for the original published paper (version of record):

Eriksson, V., Hulthén, K., Sundquist, V. et al (2021). The role of public actors in construction logistics: effects on and of relational interfaces. Construction Management and Economics, 39(10): 791-806. http://dx.doi.org/10.1080/01446193.2021.1970785



Routledge
Taylor & Francis Group

Construction Management and Economics

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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CONSTRUCTION MANAGEMENT AND ECONOMICS
https://doi.org/10.1080/01446193.2021.1970785

The role of public actors in construction logistics: effects on and of relational interfaces

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ABSTRACT
Public actors are increasingly enforcing the use of specifically designed construction logistics setups (CLS) to cope with logistical challenges and minimising disturbances on third parties in large construction projects. The organising of these CLS is contingent on the interaction among several types of actors. The purpose of the paper is to advance the understanding of the design and use of CLS and the distribution of various outcomes of such arrangements on the actors involved. The paper analyses the role of public actors in the initiating of CLS and how this affects the relational interfaces in the CLS triad of developers, contractors and logistics service providers, and the outcomes of their interactions. First, the main reason for a public actor to initiate a CLS is not cost, productivity or innovativity gains, but to decrease disturbances on third parties. Second, developers and contractors are forced to use the CLS initiated by the public actor. This makes them take on a forced customer role, explaining why these actors are often resistant to adopt to a certain CLS. Third, ripple effects, such as unintended costs and productivity impacts, occur in the construction supply chain because of the use of CLS.

ARTICLE HISTORY
Received 28 September 2020
Accepted 17 August 2021

KEYWORDS
Productivity; logistics; service; relationship; triad; cost; customer

Introduction

Construction projects are typically material intensive and generate large amounts of transports to and from sites (Josephson and Saukkoriipi 2007, Dubois *et al.* 2019). Construction logistics management should hence be a key concern in the construction industry. However, lack of logistics management has been identified as a main reason for low productivity and project cost overruns in the construction industry (Agapiou *et al.* 1998, Vrijhoef and Koskela 2000, Sundquist *et al.* 2018). Studies show that well-planned construction logistics can reduce total construction costs with as much as 20% (Löfgren 2010, Lindén and Josephson 2013). Furthermore, construction in urban areas adds to the logistics management complexity due to lack of space and disturbances on the surrounding society and the transport system (Kooragamage 2015). This, in turn, calls for sophisticated logistics management not only focussing on the site itself, but also on coordination of transports to and from sites to decrease congestion, noise, accidents, and emissions in urban areas (Janné and Fredriksson 2019).

Construction logistics can be organised in various ways with different scopes of planning and coordination (Dubois *et al.* 2019). Efforts to improve the planning and coordination of construction logistics have led to the appearance of so-called construction logistics setups (CLS) (Fredriksson *et al.* 2021). A CLS describes the way construction logistics is organised in a project including a bundle of combined services that manages and coordinates the flow of materials and resources to, from, and on the construction site (Fredriksson *et al.* 2021). The use of CLS in large construction projects is increasingly initiated by public actors. Due to the contemporary expansion in CLS utilisation, there is a need to further scrutinise the role of public actors and how the CLS design (what services are included and how actors are connected) affects the operational outcomes for the different actors involved, including the various gains and obstacles when operating in a CLS setting. The organising of CLS in construction projects is contingent on the

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interaction among actors representing developers (public and private), contractors, and logistics service providers (LSP) that form what we refer to as the construction logistics setup triad (CLS triad). The CLS triad is contingent on several types of interorganizational interfaces with various contents between the involved actors. With point of departure in the CLS triad, the involved relationships between these actors are scrutinised by applying a framework of relational interfaces (Araujo *et al*. 1999) in order to investigate how the structure and function of these relational interfaces affect the organising of a CLS and its outcomes. The paper is based on two case studies, involving two different public actors (public developers in the form of a regional council and an exploitation organisation) that initiate differently designed CLS, one used in the construction and renovation of a hospital and one used in a large city development project.

The purpose of the paper is to advance the understanding of the design and use of CLS and the distribution of various outcomes of such arrangements on the actors involved. To accomplish this, the paper analyses the role of public actors in the initiating of CLS and how this affects the relational interfaces in the CLS triad of developers (public and private), contractors and LSP, and the outcomes of their interactions. This altogether can explain the motivation for, but also resistance towards, implementing CLS. The study thus targets the intricate issue of, at the one hand, the perceived need and value of a CLS, and at the other hand, the fact that a CLS often clashes with a common view in the construction industry of the obligations and behaviours of a certain type of actor in a construction project, such as contractor, developer, and LSP.

The paper is organised as follows. First, the theoretical foundation on which the paper rests is introduced. Second, a problem discussion and research questions are elaborated on. Third, the underlying methodology is presented. Fourth, two cases are introduced and analysed. The paper ends with a discussion on the theoretical contributions, a conclusions section, and a section on future research.

Theoretical foundation

This section first introduces the CLS concept followed by a discussion of the CLS triad. Finally, the relational interface framework by Araujo *et al*. (1999) used as a basis for analysis is elaborated upon.

Construction logistics setups (CLS)

A CLS can be organised as asset-based terminal services, e.g. a construction logistics centre (CLC), or a non-asset-based service, e.g. a checkpoint service (Hamzeh *et al*. 2007, Janné and Fredriksson 2019). The aim of a CLC is goods consolidation to reduce the number of deliveries to the construction site as to cope with challenging traffic and congestion situations (Lundesjö 2015, Janné and Fredriksson 2019). Checkpoints, in turn, have emerged as a way to secure just-in-time (JIT) deliveries with booked timeslots for deliveries and specifications of delivery information, e.g. material and vehicle types, goods volumes, and handling equipment requirements (Akintoye 1995, Voordijk 2000, Sundquist *et al*. 2018).

Furthermore, a CLS often includes various value adding services (Fredriksson *et al*. 2021), such as; coordination of supplies to the site through strict rules and a booking system (Dubois *et al*. 2019), logistics-based site plans (Josephson and Saukkoriipi 2007, Transport for London 2013), site coordination (Transport for London 2013, Ekeskär and Rudberg 2016, Sundquist *et al*. 2018), materials handling on- and off-site (Lindén and Josephson 2013, Ekeskär and Rudberg 2016) and waste management (Behera *et al*. 2015, Janné and Fredriksson 2019). These services aim to improve on-site logistics (Lindén and Josephson 2013, Ekeskär and Rudberg 2016, Spillane and Oyedele 2017) and/or off-site logistics when coordinating transport to and from sites of the fragmented operations in construction (Thunberg and Persson 2014, Thunberg and Fredriksson 2018, Ying *et al*. 2018) .

A CLS can be initiated by public or private actors, such as local municipalities, public and private developers or contractors, that all have different goals with the CLS (Fredriksson *et al*. 2021). The contractor faces the challenge of managing a network of supply chains delivering different materials, products, and other resources to construction projects (Lundesjö 2015). For the contractor, the responsibility for planning and coordinating the supply chain and the construction site therefore becomes a main issue (Azambuja and O'Brien 2009). Consequently, contractors increasingly initiate CLS to streamline the on-site logistics processes (Kooragamage 2015) and/or to coordinate logistics processes across multiple projects (Lundesjö 2015). In comparison, the public actors focus on the need to coordinate construction traffic as a part of the overall traffic in a city to maintain good relationships with residents and businesses in terms of accessibility and mobility (Goldman and Gorham 2006). Depending on the purpose of introducing a CLS, the CLS can be more or less suitable to fulfil this purpose. Fredriksson *et al*. (2021) find that being aware of the goals and challenges to be managed is a good starting point when developing a CLS. This means starting in what actually needs to be managed rather than from what is technologically possible which, according to Chakkol *et al*. (2018), is often the case.

In most cases, the CLS is operated by an LSP taking the responsibility for performing logistics services during the duration of the project (Dubois *et al*. 2019, Janné and Fredriksson 2019). Furthermore, in some cases the LSP also takes on the role as systems designer by establishing the rules of conduct and what services to include in the CLS (Sundquist *et al*. 2018, Fredriksson *et al*. 2021). The more encompassing the role of the LSP, the more complex the involved business relationships will be (Fredriksson *et al*. 2021), meaning that there is a need to clearly stipulate how to govern these business relationship (Janné 2020).

Depending on how the CLS is organised the nature of the contractual relationships may vary (Ekeskär *et al*. 2019, Janné and Fredriksson 2019). There are examples of projects with several contractual relationships between all involved actors (Janné and Fredriksson 2019) or more simple and linear contractual agreements between the LSP and the main contractor, and the main contractor and subcontractors (Janné and Rudberg 2020). The interactions between the actors can be of a partner type relationship or even a peer-to-peer relationship where services are exchanged and resources shared, for example, between multiple main contractors and between contractors and LSP (Ekeskär *et al*. 2019). Norrman and Henkow (2014) highlight that traditional contracts and regulations may not be suitable for partner-based relationships where responsibilities are divided. These relationships can, however, still be contractually governed but are often less strict (Ekeskär *et al*. 2019). In these cases, control mechanisms can be informal and based on trust, commitment, and information exchange (Caldwell *et al*. 2009). Previous research indicates that relationships based on traditional contracts focus on costs and efficiency gains (Janné and Fredriksson 2019), whereas the partner-based contracts foster innovation and service development (Hedborg Bengtsson *et al*. 2018).

One challenge regarding CLS is that the initiator of the CLS is not necessarily the actor that is most affected by it (Janné and Fredriksson 2019). A CLS initiated by a contractor is more of a traditional third-party logistics setup (Marasco 2008, Fredriksson *et al*. 2021) where the LSP takes on the role as the supplier of the CLS and the contractor is the customer of the CLS. In a CLS initiated by a public actor, this is not always the case (Fredriksson *et al*. 2021). Instead, in this case, the public actor is the customer of the CLS, but contractors can be the ones who operationally are affected by the CLS and the ones that to a large extent finance the CLS through service fees, making the contractors *de facto* customers of the CLS (Ekeskär and Rudberg 2016, Janné and Fredriksson 2019). Consequently, it is difficult to ascertain who the primary customer of the CLS is (Janné and Fredriksson 2019).

The construction logistics setup triad (CLS triad)

Firms increasingly adopt a service-based business model to provide various service setups, such as CLS, which have increased the adoption of service triads (Bastl *et al*. 2019). Investigations of triads have been suggested to better understand the importance and effects of service provision in general (Wynstra *et al*. 2015) and with regard to transport- and logistics services specifically (Andersson *et al*. 2019).

A triadic approach is advocated in Andersson *et al*. (2019), that identify the transport service triad (TST) as a way to capture the connection between the exchange of goods between a buyer and seller of goods and the exchange of transport services between the buyer of transport services (either the buyer or seller of goods) and the seller of transport services. This construct is used in a construction industry setting in Eriksson (2019) where such a triad, involving a wholesaler (seller of goods and buyer of transport services), a construction firm (buyer of goods) and a transport service provider (seller of transport services) was scrutinised regarding the character of each of the involved business relationships and the interconnectedness among these business relationships. The analysis shows that a TST provides an extended analytical scope of transport efficiency compared to a firm or dyadic scope of analysis. Furthermore, it is shown how the efforts of improving (transport) efficiency from one of the involved actors' perspective might clash with other actors' views on transport efficiency but also other types of efficiency. The study concludes that interaction among the firms in the TST, enabling adjustments and adaptations of activities and resources between firms, is imperative to manage these issues.

Therefore, one way to analyse the actors' relationships and how they are affected by the CLS is by taking a triadic approach owing to the complexities of logistics service provision in construction. As such, the

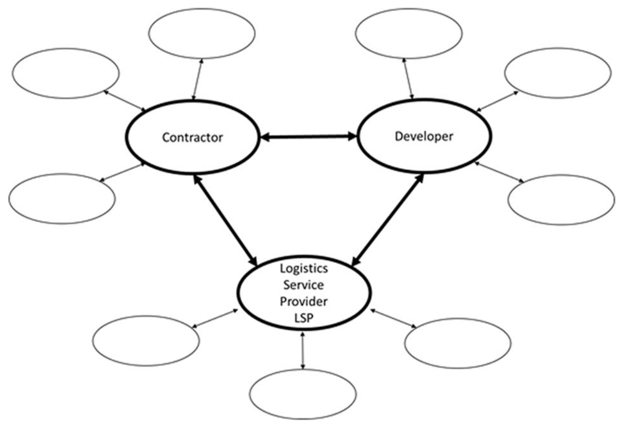

Figure 1. The construction logistics setup triad embedded in the wider network.

three actors involved in the CLS triad, as depicted in Figure 1 below, are all involved in and affected by the CLS, and also, the triad is embedded in a wider network due to the many connections each actor has to other actors beyond the triad.

Most studies on service triads take a one actor's perspective (Li and Choi 2009, Sengupta *et al*. 2018). However, central for the exploration of the CLS triad as a service triad is the interpretation of the relationships that connect the actors and also, the perspectives of all three actors involved in the CLS. Although their roles may differ depending on the specific project, the actors in the CLS triad are interdependent. Furthermore, as indicated in Figure 1, each such triad is embedded in a business network which it affects and is affected by.

Relational interfaces

The effects of various forms of interaction taking place in a CLS triad in the context of the design and operation of a CLS are scrutinised by utilising a framework developed by Araujo *et al*. (1999). The framework is based on and has been applied in industrial contexts with very clear roles regarding the supplier-customer interaction (e.g. Araujo *et al*. 2016, Andersen and Gadde 2019, Sundquist and Melander 2020) and identifies four types of relational (customer-supplier) interfaces based on how customers and suppliers relate their resources to each other. The point of departure is that firms are dependent on the resources controlled by others, and customers get access to resources controlled by suppliers by their supplier relationships.

The framework distinguishes between four types of interfaces: the standardised interface, the specified interface, the translational interface, and the interactive interface. The *standardised interface* occurs when neither the supplier nor the customer needs to be aware of each other's contexts. In this situation what is exchanged, or provided, between the parties can be managed by a standardised interaction. The *specified interface* appears when the customer wants a customised solution and therefore specifies in detail how the solution should be the designed and realised. The *translational interface* occurs when the customer instead specifies a function rather than the solution itself. This means that the supplier has more freedom to decide what resources are appropriate to use and how they should be utilised as long as the solution fulfils the customer's needs and its own logic regarding resource use. In this interface the supplier needs to translate the functional demands from the customer into a solution that is in line with the expectations of the customer. The *interactive interface* illustrates the case when the supplier and customer jointly, in interaction, develop the specifications of the solution together so that both the context of the supplier and the context of the customer could be taken into consideration when deciding on which resources to be used and how.

Depending on which type of interface is in play, the firms are provided with various opportunities and also, various impacts in terms of outcomes and prerequisites for the relationships among the firms. Araujo *et al*. (1999) identify that the various interfaces differ in terms of (1) the costs associated with the use of the respective interface and, (2) the benefits provided by them differ in terms of (a) productivity and (b) innovativity from the perspective of the customer.

Problem discussion and research questions

Li and Choi (2009) argue that a lack of understanding of triadic relationships and their dynamics is the root for failure in many service situations and further research is needed on how service triads are organised and managed (Bastl *et al*. 2019). In line with this, logistics research has been criticised for not explicating the mediating roles and implications of indirect relationships inherent in third-party logistics (TPL) situations (Selviaridis and Spring 2007). Bastl *et al*. (2019) specifically point to that service contracts impact on how the service triad is coordinated and controlled; and that the responsibility lies not with one actor but at least two actors.

The framework by Araujo *et al*. (1999) has earlier been applied primarily in the context of dyads focussing on private actors. From the literature presented above, it is evident that CLS involve different actors with different goals and challenges and that the actor roles in the CLS triad in terms of customers or suppliers are not straightforward. In the CLS triad, the LSP is always the supplier of the CLS. However, the customer role is more complex and needs to be understood in its CLS triad context, especially in the case where there is a public initiator. In line with this, RQ1 reads:

What types of relational interfaces in a CLS triad can be identified in the organising of a CLS?

Fredriksson *et al*. (2021) show that when initiated by a public actor the purpose of the CLS becomes blurred and the different actors have various purposes that can also inflict with each other. There is a need to understand how the purposes of the different actors in the CLS triad impact the organisation of a CLS. What is the difference between the initiator and user roles of the actors in the CLS triad and between the formal customer(s) in the business exchange in the CLS and the actual user of the services provided in the CLS? Furthermore, the Araujo *et al*. (1999) framework takes the perspective of the customer as point of departure for analysis of (1) the costs associated with the use of the respective interface and, (2) the benefits provided by the interfaces in terms of (a) productivity and (b) innovativity. In line with this, RQ2 reads:

What implications do different types of relational interfaces in the CLS triad have as a consequence for cost, productivity and innovativity of the organising of the CLS?

Previous research on triads in the transport and logistics context show that there are implications of how the triad is organised on the wider business network (Eriksson, 2019). The CLS actors also bring about involvement of a number of other actors such as subcontractors, materials suppliers and transport service providers etc. (Seth *et al*. 2018). Thus, the contents of the relational interfaces within the CLS triad affect and are affected by the operations of the CLS; the actors involved in the CLS triad but also, by actors in the wider business network in which the CLS triad is embedded. In line with this, RQ3 reads:

How are other actors in the wider network beyond the CLS triad affected by the organising of the CLS?

Method

Research from two research groups is combined where one research group consisting of three people has carried out three research projects over a period of seven years. The second research group consisting of two people has carried out research over a period of five years as part of five research projects. In total 20 different CLS in Sweden, Denmark and Finland have been studied. Based on these cases, the research groups identified that the phenomenon in this paper, the role of public developers in the formation of CLS triads, needed more attention. Two of the cases were selected based on the fact that they had been studied by both groups over a time period of at least five years and that they provided good illustrations of how public actors take on a more or less active role in CLS triads when organising CLS. The projects are long term (25 and 8 years time span) and complex from an organisational point of view, with many construction sites at the same time within the project area, and both have a central urban location with few available transport roads.

The first case, henceforth referred to as 'The hospital project', describes a situation where a regional council decides on a CLS based on a checkpoint in the re-construction and new build of a hospital. The second case, henceforth referred to as 'The city development project', illustrates a situation where a public exploitation organisation requires a CLS based on a construction consolidation centre in a large city development project. The two case-studies provide different perspectives on the role of public actors when initiating the use of CLS. Both are seen as public developers as they are responsible for the development, in the first case of a hospital, and in the second case as landowners in a city development area, where they also develop land for the city's own use. These two public actors are more or less active in the governing of a CLS and the cases also illustrate the role of contextual factors, such as how formal agreements are utilised. For example, in Figure 2 the LSP and the public developer have a translational interface, whereas in Figure 3 the LSP and the public developer have an interactive interface. Thus the two cases contribute to the understanding of two different settings regarding

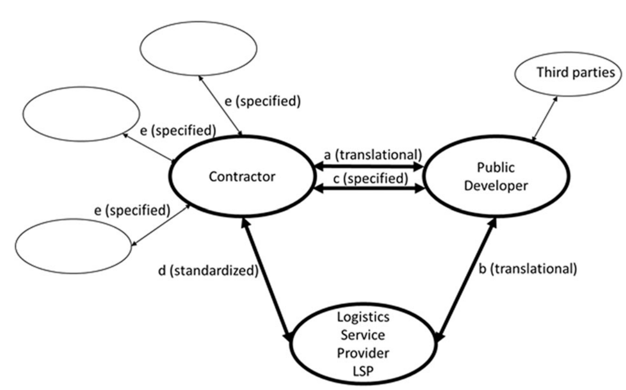

Figure 2. Identified interfaces in the hospital project.

control and access to resources, which, in turn, creates various possibilities and challenges in the CLS triad.

Table 1 below summarises the features of the construction projects in the two cases, executed as two different CLS triads in the paper.

The data collection involved interviews, observations, and a large amount of secondary data. In total, 53 interviews have been conducted with representatives from LSPs, main contractors, subcontractors, developers, municipalities, material manufacturers, distributors and transport firms (see Table 2).

The interviews were semi-structured and lasted from 1 to 2 hours. The interviews were conducted by the researchers and were recorded and transcribed. Besides general background information about the role of the interviewee, three main areas were covered in the data collection: (1) planning and execution of the CLS, including how their services relate to other operations; (2) the specific project; and (3) the interaction, information exchange and governance mechanisms amongst various actors on- and off the construction site, within the triad and in the wider network. There were also questions about the CLS in the specific projects, experiences from logistics in other construction projects and the actors' operations in general. Site visits enabled observations of the CLS and the related operations. Specifically, unloading from vehicles, site transport and logistics, delivery control and planning of resource utilisation were studied. Visits at distributors and material manufacturers

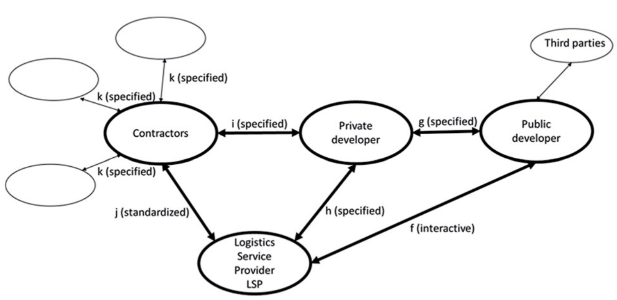

Figure 3. Identified interfaces in the city development project.

provided insights into activities such as manufacturing, storage, packaging and transport. Secondary data in the form of site disposition plans, tenders, materials handling directives and information from delivery planning systems were crucial to understand the function of CLS and its effects for various actors.

The research method is based on an abductive logic in line with systematic combining as empirical data and theory were systematically combined in an iterative process (Dubois and Gadde 2002). For example, the intention from the beginning was to cover more general aspects in the actor interaction in the two cases. However, as the data revealed interesting aspects of the interaction between developers, contractors and LSPs in the design and use of CLS, this analytical focus emerged during the process. The developer role of the public actors in the cases was found especially interesting since it showed to have great impact on the outcomes of CLS. To analytically approach this issue, theory of triads and the identification of three generic actor roles (public/private developers, contractors and LSPs) and the relational interface framework by Araujo *et al*. (1999) were successively identified and used. The analysis of data started with the identification of the actors in the two CLS triads, including the connections among actors in the respective triad, and central connections between the respective triads and its surrounding network. This mapping was possible through the combining of data from the interviews, site visits and secondary data. Each connection, now labelled relation interface, was then classified by using the framework. The result of this analytical process is illustrated in Figure 2 (the CLS triad in the hospital project) and Figure 3 (the CLS triad in the city development project). Finally, outcomes in the form of costs, productivity and innovativity were identified as effects of the identified interfaces (see Table 3). The research process has thus been a nonlinear, path-dependent process with the objective of matching theory and the empirical world (Dubois and Gadde 2002). Accordingly, during the

Table 1. Features of the projects in the two cases.

Type of construction project	Project-specific logistics setup	Location of construction/ development project	Scope of construction/ development project	Construction/ development project time-frame	Data collection
The hospital project	Yes	Central location, adjacent to existing operations and business locations	4 new buildings 66,000 m^2 of hospital area. Renovation and re-build of existing hospital	7 years	28 interviews, 2 site visits
The city development project	Yes	Central city location, adjacent to existing housing, business locations, and ports	12,000 apartments and single-family houses 35,000 new workplaces	25 years	25 interviews, 7 site visits

Table 2. Interviews in the study.

	Companies	Number of interviews and function of interviewee
The hospital project	LSP – site staff	8 (2 logistics managers, 2 logistics coordinators, 1 material delivery planner, 1 work manager, 1 arrival controller, 1 quality manager)
	LSP – central management	6 (2 business developers, 2 logistics consultants, 2 materials handling managers)
	Four contractors	4 (3 site managers, 1 work manager)
	Two subcontractors	2 (2 work managers)
	Two distributors	3 (1 logistics manager, 1 store manager, 1 sales manager)
	Transportation firm	2 (1 transport leader, 1 chauffeur)
	Management consultancy firm	1 (1 project manager)
	Materials manufacturer	1 (1 sales manager)
	Project management firm	1 (1 project manager)
The city development project	Municipality	4 (1 development area manager)
	LSP	9 (4 CLS managers, 2 logistics coordinators, 1 arrival controller)
	Four contractors	4 (3 site managers, 2 logistics coordinators)
	Eight developers/clients	8 (8 project managers)

research process, the cases developed into illustrations of relational interfaces in CLS triads and the various roles of public developers in such triads. The data from the case studies enabled the capturing of the phenomenon of how the three generic actors (contractor, LSP and public/private developer), in a CLS triad affect and are affected by the organising of a CLS. Furthermore, the in-depth data from the case studies in terms of actor interaction was considered critical to understanding the dynamics of the business context (Halinen and Törnroos 2005). In line with Dubois and Gadde (2002), this paper relies on analytical generalisation rather than statistical generalisation. The above description of the abductive nature of the research process aims to show how credibility has been accomplished in this study.

Two cases of construction logistics service triads (CLS triads)

In this section, first, the hospital project is presented, followed by the city development project.

The CLS triad in the hospital project

In this case the public developer in the form of a county council tendered a contractor for the re-construction and new build of a hospital. In the tendering process the developer specifically pointed to the intricate issue of construction logistics as the hospital would be fully operational during the construction process. The contractor had to assure that by no means would hospital operations be jeopardised, and the organising of construction logistics had to take into account the large amount of health care personnel, patients and visitors in transfer on the hospital area. In particular, as the construction gate would be located next door to the ambulance entrance, the monitoring of construction transport was crucial. Additionally, lack of space on the construction site would only allow one vehicle to be on site at a time, and vehicles could not wait outside the gate. When the contractor presented its own internal setup in terms of how to organise construction logistics, the developer figured that it was not sophisticated enough and that the risks in relation to the critical logistics had been overlooked. Therefore, the developer decided that the contractor had to use an external LSP that was going to be responsible for the CLS, whereas the contractor would be responsible for production. The developer assigned the contractor to tender the LSP selected by the developer. Thus, in this arrangement the contractor "lost" an important part of what they usually had included in their contract with the developer, the on-site logistics. Furthermore, the contractor could not decide which LSP to use and what services to be included.

The LSP has developed a portfolio of logistics services based on many years of experiences from various logistics setups in different construction contexts and projects. The services are standardised and benefit from specialisation in terms of economies of scale in on-site logistics operations. However, the combination of various services is adapted to unique customer needs and the specific conditions in each project. In this specific case the CLS involved a checkpoint run by personnel from the LSP stationed at the site. The LSP took care of the coordination and monitoring of all deliveries to the site with their web-based delivery planning system, including updates of on-site disposition plans. The LSP also carried out all materials handling, including unloading of materials, quality control

Table 3. Interfaces in the CLS triad and their effects on costs, productivity and innovativity.

	Interface type	Costs	Productivity	Innovativity
The hospital project	Developer - Contractor: translational interface (a)	None (no contract for logistics services)	None (no contract for logistics services)	Loss of opportunity for the contractor to innovate its logistics services
	Developer - LSP: translational interface (b)	No costs for the developer, no costs for the LSP	On site: Increased productivity due to LSP's ability to use standard CLS operations	Limited opportunity for innovation as the developer lacks knowledge of the LSP's context
	Developer - Contractor: specified interface (c)	Cost for the CLS enforced on the contractors	On site: Increased productivity for contractors if adjusting to the requirements from the developer regarding use of the CLS	None as contractors must adapt to the developer's requirements
	Contractor - LSP: standardised interface (d)	Costs for the contractor for using the CLS	On site: Increased productivity for materials handling and construction activities	The coordination meetings held by the LSP facilitated contractor interactions and joint problem-solving regarding materials supply
	Contractor – Suppliers: specified interface (e)	Costs for suppliers due to need of adaptations to the CLS	Off site: Decreased productivity for materials supply and manufacturing	None: suppliers must adapt to the contractors' requirements
The city development project	City of Stockholm – LSP: interactive interface (f)	None as the City of Stockholm does not pay for operation of the CLS	On site: Potential increase of productivity Off site: potential increase in productivity in regard to transports to site	The CSL as an innovative setup based on combined knowledge and experiences Put focus upon logistics from the beginning of projects The LSP perceives hinders for continuous improvements over time when the CLS is operationalised.
	City of Stockholm - Developers: specified interface (g)	Costs for the CLS paid by developers in land allocation	None	None: developers must adapt to the requirements by the City of Stockholm
	Developers – LSP: specified interface (h)	Costs for developers as indirect customers to the LSP	None	–
	Developer - Contractor: specified interface (i)	Costs for the CLS enforced on the contractors.	On site: Potential increase of productivity of contractors if adaptations to the requirements from the developer regarding use of the CLS	None: contractors must adapt to developers' requirements
	Contractor - LSP: standardised interface (j)	Costs for contractors for mandatory logistics services. Less income than expected for LSP: sell less than promised of extra services.	On site: Increased productivity for materials handling and construction activities. On site: Reduced productivity in planning for contractors due to allocation of more resources and time for planning	The possibility of storing and calling off materials in smaller batches were considered positive by the contractors. The activity coordination meetings held by the LSP facilitated the interactions among contractors and joint problem-solving regarding materials supply.
	Contractor – Suppliers: specified interface (k)	Costs for suppliers due to need of adaptations to the CLS	No particular effects observed	None: suppliers must adapt to the contractors' requirements

and transport of materials to the correct installation area at the site. All deliveries to the site had to be booked by contractors in the system at least five days in advance and deliveries were scheduled according to time slots of 30 minutes. All deliveries had to pass through the checkpoint located a few minutes from the construction site and obtain approval to proceed to the onloading area at site. Contractors paid a fixed fee per unit of materials handled by the LSP, and goods should preferably be delivered on pallets to be transported by pallet lifts into construction elevators at the site. All materials handling took place after regular working hours between 4 pm and midnight by the LSP's personnel as to minimise disturbance in the transport of on-site personnel by elevators during day-time and hampering other logistics flows of transports and people in close proximity to the site. Logistics efficiency is thus improved on site by using the CLS by the LSP.

All contractors on site had to follow the logistics setup provided by the LSP. However, these requirements were not taken into consideration in every tendering process. As a consequence, contractors who did not take the delivery fee into account in their tenders for the contract had to 'pay twice' for materials handling: to the LSP and to cover for the hours of construction workers who normally carry out materials handling as part of union agreements. Thus, although contractors now performed 'only' production activities on site, it was difficult to make use of the extra hours gained from not being involved in materials handling in an efficient way. In some cases, transport after regular working hours also entailed extra costs for the contractors. Furthermore, suppliers had to adapt their off-site operations to be able to deliver off-working hours and also to follow the strict packaging instructions enforced by the LSP. An intermediate storage had to be established by some contractors to be able to cope with the challenging just-in-time (JIT)-delivery prerequisites at the site since no materials was allowed to be stored on site due to lack of space. The extra intermediate storage came with an extra cost for these contractors.

All in all, the enforced situation where the main contractor had to tender the LSP and its CLS by the requirements from the developer created tensions between the main contractor and the LSP. This also applies to the relations between the LSP and many of the subcontractors. However, as the project progressed the interaction among the actors improved as the contractors learned to adapt planning and execution of its operations in accordance with the CLS. Also, several contractors stated that it would have been impossible to have efficient construction on site without the CLS as the logistics challenges were severe including the extensive need for coordination of logistics in relation to the many actors present on the site. Due to the use of a checkpoint, no disturbances occurred in the hospital area regarding flows of hospital supplies and other traffic. However, in close proximity to the site, vehicles waiting for access to the checkpoint created disturbances in traffic as they occupied road service areas and roadsides.

The CLS triad in the city development project

In this case the public developer, in the form of a publicly owned and controlled exploitation organisation, had specified several logistics requirements in relation to a development program where an old industrial area was going to be transformed into a new city area. In this area, the exploitation organisation developed parts themselves and sold other parts to different private and other public developers. Therefore, the development program involved many projects with many different actors. The public developer initiated the development of a CLS to reduce the amount of construction traffic in the construction area as well as to contribute to sustainable transport by reducing the construction traffic to the construction area. The developers in each project were forced to join and commit to the CLS if they wanted to buy land and be part of the development program. Hence, the use of the CLS was mandatory for all contractors acting within the area and they were governed through contractual agreements between the public developer, LSP, private developers and contractors. It was stipulated in the land allocation agreements that all developers were required to inform their contractors of the CLS, and the mandatory use of some basic services offered in the CLS.

For the operating of the CLS the public developer tendered an LSP that they had experience of from a previous city development project. The public developer could thus specify requirements in terms of a customised setup adapted to the location and site conditions, based on their knowledge of the services of the LSP. The CLS comprised of a construction logistics centre (CLC) in the form of a terminal and additional logistics services such as, traffic piloting, education, perimeter fencing, and security. Each sub-project had its own unloading zone. The rules of conduct of the CLS were developed jointly between the public developer and the LSP. Accordingly, all incoming transports had to be booked into a transport booking system five days in advance, and no materials storage on-site was allowed. Instead, intermediate storage in the terminal would cover for some short-term storage. There was a common waste disposal system with smaller waste containers on-site which were collected by a sub-supplier to the LSP. In addition there was a common perimeter fencing with gates, provided by another sub-supplier to the LSP. All material deliveries under a certain volume had to be consolidated and vehicles longer than 12 m had to have a special permit to enter the construction sites. Except for following these rules, it was possible for each contractor or developer to set the rules on their sites and what additional services to buy from the LSP. As a result, the LSP had to adapt its way of working and how to make use of its resources in a way that fulfilled the specified demands of the various developers. The cost for the CLS was covered by a fee in relation to the land allotment and by contractors and subcontractors paying for the logistics services.

The contractors had frequent (at least weekly) contact with the LSP as they were responsible for the development area coordination and booked all deliveries and use of machinery through a booking calendar. There was an extensive follow up on the use of the services and costs by the public developer, which were thereafter feedbacked to the developer and the contractors. All in all, some positive effects were identified, and several contractors admit that it would have been impossible to work in the area without the CLS due to the many simultaneous operations in the many projects. The main challenge with the CLS was to convince and 'sell' the idea to all parties. The public developer was convinced that the CLS would bring cost savings to the contractors. However, since the CLS was organised mainly to reduce disturbances, the cost and productivity gains of contractors did not come out as planned. Only a few contractors bought additional services besides the mandatory basic services. Furthermore, developers viewed the developer-contractor information exchange as troublesome.

Analysis

The analysis is based on three themes in relation to the research questions: (i) characteristics of interfaces in the CLS triad, (ii) implications of various interfaces for the actors involved in the CLS, and (iii) the CLS triad as embedded in the wider network.

Characteristics of interfaces

The section starts with an analysis of the the hospital project case and continues with an analysis of the the city development project case. The identified interfaces in the respective CLS triad are illustrated in Figure 2 for the hospital project and in Figure 3 for the city development project. For the hospital project the different interfaces identified are marked with letters *a*–*e* and for the city development with letters *f*–*k*.

In the case of the hospital project, the public developer started with acknowledging the challenging logistics conditions, and from the beginning the interaction with the contractor was based on a translational interface (*a*) as the developer asked the contractor to create a CLS based on the needs of the developer. However, as the contractor could not adhere to this and did not come up with a suitable setup, the developer instead turned to the LSP regarding the need for a CLS. The developer in the role of a customer thus expressed certain demands in the form of a translational interface (*b*) serving as input for the development of a CLS by the LSP. Based on this, the LSP translated the developer's needs into a CLS based on its standardised operations, as to benefit from utilisation of already established routines and resources. Consequently, the customer-supplier contract between the developer and the contractor came to involve 'only' production, with a content of a specified interface (*c*) regulating that the contractor had to use the LSP and its services for logistics operations. However, details regarding the content of the CLS was not part of this interface. The LSP hence became the supplier of logistics services to the contractor, that was forced by the agreement with the developer to pay for the CLS, and thus, it became the formal customer to the LSP. The collaboration between the contractor and the LSP is thus contingent on a standardised interface (*d*) as the contractor had no ability to affect the services provided. The interfaces between the contractor and the subcontractors as well as between the contractor/subcontractors and their respective materials suppliers and transport providers are specified (*e*) as the contractor 'pass on' the demands regarding the use of the CLS to these actors, based on the requirements for using the CLS and their logistics operations.

In the city development project the public developer role exists on two levels. The public developer had previous experiences of working with a specific LSP from another development program. In the city development program, they therefore initiated the development of a CLS in an interactive interface (*f*), taking into account both actors' knowledge and conditions. In the role of the supplier of land, the public developer conditioned land allocation to its customers, the various private developers in different projects, by specified interfaces (*g*) directing all developers to set demands on their suppliers (contractors) to use the CLS. Consequently, specified interfaces (*h*) between the private developers and the LSP arose, as these developers partly paid for the CLS by land allocation fees. The logistics requirements were in turn forwarded to the contractors. Hence, also the interface between private developers and contractors were characterised as specified interfaces (*i*), as a direct consequence of the interface between the public developer and the private developers. Each contractor had the opportunity to buy additional logistics services, besides the mandatory basic services, in the CLS provided by the LSP. Furthermore, contractors also called for logistics services, for instance, intermediate storage of concrete elements, that were not provided by the LSP. Private developers did not pay for the direct utilisation of the basic services, as the cost for the CLS was covered partly by land agreements between the public developer and private developers. Instead, payments for the utilisation of the CLS, including the option for additional services, were covered by the contractors who, by their customer-supplier interfaces with private developers, were forced to adhere to the CLS. The respective interface between contractors and the LSP were thus characterised as standardised interfaces (*j*), as contractors in their roles as customers had to buy the basic services from the LSP, based on the public developer's requirements enforced through the private developer's requirements. The interfaces between the contractor and the subcontractors, as well as between the contractor/subcontractors and their respective materials suppliers and transport providers are specified (*k*) as the contractor 'pass on' the demands regarding the use of the CLS to these actors.

Implications of interfaces for CLS triad actors

The implications of the interfaces on the actors involved in the CLS triad are analysed below and summarised in Table 3. The discussion of interfaces in the previous section points to that the customer-supplier roles in the two CLS triads are blurred with regard to the relational interfaces between contractors, developers, and LSPs. The different interfaces create various effects for the LSP depending on which type of interface is established by the customer. The analysis shows that the CLS is initiated by the public actor as part of their developer role but operated by an LSP, exemplified in interfaces (*b*) in the hospital project and (*f*) in the city development project. However, it is not the public developer that pays for the CLS and when the actor initiating the CLS does not pay for the setup, the cost is instead regulated in other interfaces. In the hospital project, the contractor (and subcontractors) are the ones paying for the CLS, regulated in interface (*d*). In the city development project, the cost for the CLS is partly covered in interface (*g*) between the public developer as a land owner and the other developers involved in the development program, but also in interface (*j*) between the contractors and the subcontractors and the LSP. Consequently, in both projects the contactors are forced to pay for the CLS provided by the LSP and align with the CLS as a consequence of the interface (*c* and *i*) with their customers. Hence, it is not a free choice of selection of LSP (supplier) and consequently earlier experiences of perceived benefits of other suppliers from the perspectives of contractors cannot be taken into consideration. As such, there is an intricate interplay between the various interfaces in the CLS triad that affects how the costs of the CLS are distributed among the actors. Costs in this sense do not only relate to 'payments' for the CLS but also for maintaining the respective interface in relation to the CLS. Furthermore, one aspect is the cost in relation to the CLS that is visible in the tendering process, as in the specified interface (*g*) in the city development project based on the requirements in the land agreement, and in the developer-contractor interface (*i*). In comparison, in the hospital project, the contractor is tendered prior to the conditions for the CLS being set (interface *a*), wherefore, associated CLS costs are not part of the developer-contractor contract but appears later on in the process. There is also the case of extra costs because of how the CLS and the related stipulated logistics conditions align with the contractors' processes, where additional costs occurred as an extra intermediate storage became necessary to secure construction operations (hospital project) or fulfilling rules of conduct (city development project).

Furthermore, the interfaces including the interplay between them also provide effects in terms of how they contribute (or not) to productivity and innovativity, for individual actors, but also in respect to total project productivity and innovativity. As in the effects of costs stemming from various interfaces, the analysis shows a somehow uneven distribution of the effects with regard to productivity where potential productivity gains sometimes are hampered by the fact that conditions for the CLS are set after contractors have been tendered, as in the hospital project. This decreases the contractors' abilities to take the CLS into consideration in their construction planning.

In the case with the interactive interface (*f*) between the public developer and the LSP in the city development project, the ambition revolved around (1) the creation of on-site productivity of logistics and (2) increased productivity for (non-construction related) transport to reduce disturbances from construction traffic. Hence, in both these cases the standardised interfaces (*j*) between the contractors and the LSPs enhanced productivity on site with regard to materials handling and construction production activities respectively. However, for the various contractors on site it was difficult to make constructive use of this enhanced productivity as this would require redistribution of resources in the form of personnel and/or equipment to other sites or a different setup in terms of planning for allocation of resources in the start of the project. Also, in the hospital project, the standardised interface (*d*) and how those demands are causing effects via interfaces (*e*), shows how the CLS acquired was mainly approaching on-site logistics and did not consider off-site effects. This resulted in improved conditions for productivity on site but hampered the productivity off-site among material suppliers.

The interactive interface (*f*) between the public developer and the LSP in the city development project shows that when a supplier and an initiater jointly, in interaction, develop the specifications of the CLS, taking into account both actors' contexts, a CLS can be created that copes with initiaters needs along with efficient use of the suppliers' resources. However, as the initiator in this case was not the user of the CLS, the users' operational needs to increase productivity were left out during the design process. The other interfaces in that CLS triad are characterised by a more limited freedom with regard to use of resources for both customers and suppliers in the interfaces between developer-LSP (*h*), developer-contractor (*i*) and contractor-LSP (*j*) respectively.

Lastly, it should be highlighted that the CLS are initiated and designed primarily as to decrease disturbances in the construction processes and for third parties and not to increase productivity, costs or increase innovativity. Thus, the focus of the interfaces (*a* and *g*) between the initiator (public developers) and the LSP was to improve conditions for third party actors in the public domain, i.e. in the hospital project ambulances and other hospital operations, and in the city development project inhabitants of the city.

Table 3 below comprises a compilation of the effects due to the identified interfaces in the two CLS triads.

Implications for the wider network

The features of the CLS mitigate through the CLS triad as a result of the interface characteristics and the interplay among various interfaces that, in turn, impact on costs, productivity, and innovativity among the actors of the construction project. This, in turn, impact on other actors beyond the triad. Furthermore, interfaces to actors outside the CLS triad affect the CLS triad and the outcomes for those actors. This is also evident in the cases where both CLS are initiated due to a need to reduce disturbances on actors outside the CLS triad such as third parties in the form of ambulances, health-care personnel, citizens, offices etc. For example, in the city development project, the responsibility of the public actor to provide for reduced disturbances for third parties due to fewer vehicles in the area is crucial. Thus, interfaces to those actors outside the CLS triad have a severe impact on the CLS.

However, the interfaces within the CLS triad also impact on actors outside the triad in the supply chain. In both projects, the interface between the contractor and the LSP aiming for increased productivity on-site, had effects for carriers and suppliers upstream the supply chain since they had to adapt their standard routines to the CLS. Demands regulated in the standardised interface between the contractor and the LSP (*d*) were passed on via the interfaces (*e*) to subcontractors, materials suppliers and transporter providers, thus generating additional costs for these actors. This is no surprise as the design and operation of the CLS are focussed on on-site conditions, with effects on productivity on site, and not to improve productivity in the total supply chain encompassing materials suppliers and their operations. However, one exception is the productivity regarding transport as it increases when bundling of deliveries is applied. Hence, in the hospital project actors upstream the supply chain acting as suppliers to contractors with specified interfaces (*e*), the standardised interface between the contractor and the LSP (*d*) in relation to on-site conditions led to adaptations beyond normal routines which decreased their productivity making use of their resources. The same logic applied for the subcontractors in both projects as they had to adapt to the CLS, and thereby act as customers to the LSP by paying for its services, not by choice but by conditions stipulated by the developer. Therefore, as a consequence of the ambition to cope with challenging logistics conditions on the site and decrease disturbance on third-parties, the interfaces in the CLS triad force other actors in the wider network of the CLS triad to adapt to the CLS initiated by a public actor. Commonly, this clashes with the established productivity logic and established routines of these private actors.

Furthermore, both cases show that previous interfaces, prior to the projects under study, play a crucial role. In the hospital project, previous interfaces to various customers in the form of contractors and developers have enabled the LSP to provide for a standardised CLS, that is central for their efficient use of resources, and in turn, enables effects of increased productivity in logistics operations on site as well as reduced disturbances on third-parties. The LSP can exploit the CLS to its fullest, as the developer has no previous experience and thus has to rely on the skills of the CLS without being able to specify demands but leaves it up to the LSP to design and operate the CLS via a translational interface. Also, in the city development project, the previous interface between the public developer and the LSP is crucial for the design of the CLS. Thus, interface analysis of a particular project's CLS triad must take into consideration how interfaces relate over time, beyond the project boundary, both prior to the CLS triad in focus, but also after, in terms of learning and experiences gained in the CLS triad that might affect how customers and suppliers behave in future interfaces.

Discussion of theoretical contributions

As a response to Bastl *et al*. (2019) we have developed the foundation for how service triads are organised and managed, which should be seen as a theoretical contribution. The unique aspect of the CLS, which has not been covered in the research of transport service triads (TST), is *the forced customer role,* a central aspect in relation to the roles of customers and suppliers in the CLS triad. The customer in the form of a contractor might be unwilling to access the resources of the supplier (the LSP), but is despite that forced to pay and use the services. This is a consequence of its role as supplier to a developer that enforces the use of the LSP. This forced customer role creates a resistance from the enforced customer to support the CLS. Hence, this paper shows that these initiatives are not driven by an understanding of the need to improve logistics. This is a contribution to the construction logistics area, as this to some extent explains the lack of comprehensive implementation of logistics and SCM in construction (e.g. Vrijhoef and Koskela 2000, Bankvall *et al*. 2010).

This leads us to our second theoretical contribution. As a response to the critique presented by Selviaridis and Spring (2007), we are explicating the mediating roles and implications of indirect relationships inherent in TPL situations. In previous studies of CLS (e.g. Janné and Fredriksson 2019), we also identify two types of customers to the same CLS. The first type of customer, the public initiatiator, acts to improve the common good with the goal to decrease the disturbances on third parties. However, the main objective of the second type of customer, private contractors and subcontractors, who are the users of and pay for the services, is to improve costs, productivity and innovativity in line with original intentions of the framework by Araujo *et al*. (2016). Thus, findings show a clash between the incentives and goals of public actors with construction logistics, with the responsibility of reducing disturbances for third parties, and the business models of private developers, contractors and LSPs involved in the CLS triad. Therefore, to some extent the demands set by public developers interfere with the logics in these business models, and thus, a new performance indicator, disturbances, was introduced in the context of CLS. Thus, this application of the Araujo *et al*. (2016) framework to a new context contributes to its further development. The framework has earlier been applied in industrial contexts with very clear roles regarding the supplier-customer interaction and only private actors (e.g. Araujo *et al*. 2016, Andersen and Gadde 2019, Sundquist and Melander 2020). Though, here we show that the performance indicators are dependent on the context of the triad.

Li and Choi (2009) argue that a lack of understanding of triadic relationships and their dynamics is essential to their implementation success. This paper shows that the interfaces are dynamic and develop over time. This is evident from the two studied cases where the perceptions regarding the use of a CLS among the contractors shifted from highly negative to slightly positive during the project. This can be regarded as business opportunities as the actors learn over time and can adapt their resource base in a way that enable them to cope with future similar situations in a way that is less negative for them. However, the common temporariness of the relationships in construction projects is identified as a hinder for such development. In line with previous studies, applying the interface framework identify great potential in high involvement interfaces as long term relational investments (Araujo *et al*. 1999, Andersen and Gadde 2019), the features of the construction industry with strong reliance on competitive tendering and focus on individual projects, affect the possibilities of exploitation of interfaces as investment.

A third theoretical contribution relates to the CLS research stream and highlights the importance to analyse CLS as a triad in a wider business network (Eriksson, 2019). One important aspect regarding the various consequences concerning costs, productivity and/or innovativity is the fact that the applied interface among customer-supplier is heavily embedded in several other interfaces: thus, it affects other actors in the network. An interface might enhance productivity in a certain part of the supply chain, for example on the construction site, while it hampers productivity more up-stream the supply chain. Innovation is also affected. For example, by specifying a CLS very strictly in individual projects, innovative setups might be hindered as the involved actors cannot develop and combine its resource collections into new solutions. Furthermore, the focus of the public initiators to decrease disturbances on third parties, removes focus from how the CLS impacts the actors in the construction project and supply chain. Hence, each actor's perspective is limited by its network horizon (Holmen and Pedersen 2003, Eriksson *et al*. 2020) but even if the network horizon is rather wide it can be very hard to interpret the perspectives of other actors and foresee certain effects from these actors' perspectives.

Each actor also has a unique perspective on what is a suitable CLS for each specific context depending on what type of role the actor has, i.e. contractor, LSP, developer, supplier, or customer. The exchange of such perspectives can be promoted by early interactions among the actors in the CLS triad. Consequently, the selection of one interface should be the outcome of decisions that take into account not only the content of the interface among supplier and customer, but the wider picture of how other actors are affected, both within and beyond the focal CLS triad. Benefits perceived by the initiator of the CLS must be balanced against the investments that have to be made among the many actors who have to align to the CLS. In order to get acceptance for such a CLS it is therefore important that a discussion of the distribution of costs is held early in the process and that this is accepted by all parties in the CLS triad. Reaching this consensus early on means that it will also be easier for each of the three parties in the CLS triad to forward the message in their respective part of the wider network.

Conclusions

The purpose of the paper is to advance the understanding of the design and use of CLS and the distribution of various outcomes of such arrangement on the actors involved. In the forthcoming two sections we articulate the theoretical and managerial contributions of the paper.

Theoretical contributions

In line with the discussions on the theoretical contributions the paper contributes to (1) the construction logistics literature and (2) the framework originally developed by Araujo *et al*. (1999) and how it can be used (and developed) in a triadic setting depending on context. To the construction logistics research we contribute by highlighting the need to analyse the CLS from a triadic perspective and as embedded in a wider network to explain the implementation resistance of the CLS. Second, when a public actor is the initiator of the CLS, the initiator role and the user role need to be separated in the CLS triad. The paper shows that the framework by Araujo *et al*. (1999) is very suitable for analysing a CLS in a triadic setting. However, the performance indicators need to be adapted to the context. This is illustrated in the paper through the introduction of the disturbances performance indicator, stemming from the public actor initiative.

Managerial contributions

The forced customer role in CLS as a result of the CLS being initiated by a public actor shows that for contractors it is important to be able to adapt the resource base and interaction in various interfaces based on different types of CLS. To decrease the cost of CLS and increase the innovativeness of the implementation, the contractors need to develop strategies of how to combine internal resource bases with resources of various other actors and CLS. For public actors initiating CLS, on the other hand, it is important to increase their understanding of how the demands of a certain CLS affect other actors. As a general guideline, they need to elaborate on their goal of decreasing disturbances in relation to the contractors' goals of productivity. Public actors can through policies regarding the use of CLS in public development project help to enhance the advancement of productivity and innovativity in the construction industry. However, considerations need to be taken with regard to the potential negative effects in terms of uneven distribution of costs and gains, which might cause resistance to use CLS. In conclusion, interaction in early stages with possibilities to influence the CLS is a key aspect for all actors, affecting the ability to design the CLS to exploit and develop internal resource bases in interaction with other actors' resources. A key achievement for the LSP is also to cope with the forced customers and to manage the interaction with those actors as to provide for a smooth process in the combining of various resources.

Future research

The paper is based on examples where public actors play a significant role in the organising of construction logistics and hence, the outcomes for various actors. More studies are required to advance the understanding of this role in relation to various contextual factors, distribution of outcomes, and connections over time across various projects. Thus, despite the generic role in the form of of the public developer, the behaviour, intentions and effects are by no means generic, wherefore more studies could add to the multifaceted role public actors play.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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