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Actor roles and public–private interaction in transitioning networks: the case of geofencing for urban freight transport in Sweden

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Abstract

Purpose – This paper aims to investigate actor roles and public–private interactions in networks. Role dynamics are explored in two settings: the current development network and the future implementation network to which actors are transitioning.

Design/methodology/approach – The paper builds on the industrial marketing and purchasing approach to business markets and uses a qualitative methodology. A case study of a network developing geofencing applications in the context of sustainable transport was used. The main source of data was interviews with 26 respondents from public and private organizations.

Findings – Roles in development and implementation of geofencing are identified, where private and public actors may take on one or several roles in the developing setting. When transitioning to the implementation setting, the expectations of public actors vary and there is ambiguity over their roles, which range from active to inactive. This detailed empirical case study shows the complexity of multi-actor involvement when developing digital technology for the transport system.

Research limitations/implications – The study highlights the transition from firm-centric innovation to network-centric innovation and its implications on actor roles.

Practical implications – Organizations participating in public–private innovation networks need to be aware of the multiple roles public organizations play and the complexities they face.

Originality/value – The paper explores role dynamics within and between the development and implementation settings of geofencing. Within the current development setting, roles are identified at different organizational levels with limited change in role dynamics. When transitioning to a new setting, actors' role dynamics may range from "limited" to "path-breaking." In future settings, actors enter and exit networks and their roles may change dramatically.

Keywords Transport innovation, Role dynamics, IMP, Interorganizational interaction, Intelligent transport system

Paper type Research paper

1. Introduction

This paper investigates actor roles in public–private network interactions. The empirical focus is new technologies in the context of urban freight transport systems. Because of technology advancement, opportunities to work with new digital tools have received increased attention within urban freight transport (Olia *et al.*, 2016). Digitalization in this area can contribute to more efficient use of vehicles and infrastructure while increasing the service level provided by freight operators (Pernestål *et al.*, 2021). Intelligent transport systems (ITSs) enabled by information and communication technology are emerging quickly and aim to mitigate the challenges of urban freight transport, contributing to lower emission, safer and more attractive urban environments, without having a negative impact on transport and business operations (Agarwal and Alam, 2018).

However, despite having significant potential to contribute to sustainable freight transport systems, these tools are rarely implemented on a larger scale because of a lack of clear business models (Asselin-Miller *et al.*, 2016), collaboration and coordination between actors (Turetken *et al.*, 2019). Furthermore, ITSs often rely upon several crucial factors, such as multi-actor collaboration, complex data sharing processes, new business models, public–private interaction, introduction of new actors and shifting roles of existing actors (Cooper *et al.*, 2019; Leviäkangas and Öörni, 2020; Whittle *et al.*, 2019; Zlocki *et al.*, 2019).

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A technology within ITS that illustrates these aspects is geofencing. Geofencing is defined as the delineation of a geographical zone by a virtual perimeter that automatically detects the entry or exit of tracked mobile units (phones, vehicles, etc.) using geopositioning (GNSS/GPS) (Reclus, 2013). For traffic-related applications, this means that a virtual perimeter detects when a vehicle or other road users enter or exit a defined geographical area and triggers an action, such as a toll payment, switching the powertrain in a hybrid vehicle, triggering a warning signal and adjusting the vehicle's speed (Foss *et al.*, 2019). This technology has been used, for instance, to automatically reduce the speed of vehicles approaching school areas or to ensure that hybrid heavy goods vehicles (HGVs) run in electric mode when driving in central urban areas at night. Although geofencing is considered to contribute to increased social and environmental sustainability by improving traffic safety and reducing emissions, it is still a technology in its infancy, and little is known about the emerging roles of existing and new actors in the network or how they interact.

New technologies and digitalization trigger the reconfiguration of relationships between actors, especially in innovative environments (Yoo *et al.*, 2012) within which relationships and interactions are crucial for success (La Rocca and Snehota, 2014, 2017). Digitalization affects how actors exchange data and how that data is analyzed and used to improve operations, which affects the interactions and value creation of the actors involved (Sjödin *et al.*, 2020). Complex innovation that requires the connecting of resources and actors across boundaries implies a shift from firm-centric to network-centric innovation (Coughlan, 2012). The development of geofencing requires many organizations to interact, often in new ways and with new actors. In this case, in which business models are based on data and algorithms, interactions between actors and networks are essential for the implementation of these business models. This implies that interactions between actors and the expectations of them become more complex. Therefore, the industrial marketing and purchasing (IMP) approach (Håkansson and Snehota, 1995) will be a suitable tool to analyze and understand these complex settings.

Actors' positions and roles within a network are important aspects (Mattsson and Johanson, 1992). In Linton (1936) defined a role as the behavior adopted by an actor in individual interaction processes. Since then there has been further discussion of roles in networks, including how actors can take on different roles through their interactions and how they change over time, resulting in the development of new characteristics (Guercini and Runfola, 2015). Anderson *et al.* (1998) conclude that actors' decision-making depends on how they interpret their own roles and positions within a network, which in turn can depend on other actors' expectations or the intentions of focal actors. Thus, certain aspects of a role point to current functions or positions, future expectations and relationships between roles. Several studies have looked at roles in the context of business networks; for example, the changing roles of middlemen (Olsson *et al.*, 2013), the roles of university spin-offs in networks (Aaboen *et al.*, 2016) and actors' roles in local innovation systems (Guercini and Runfola, 2015).

Developing and implementing geofencing involves a network of both public and private actors within the transport system. Because geofencing is incorporated in the transport system, this study includes actors that are influencing, developing and using the technology. As geofencing is still under development, no major player has taken a leading role and there are uncertainties over what the contributions of different actors should be, making this an interesting empirical setting to study. In the developing setting, actors may occupy a number of different roles (Guercini *et al.*, 2020; Wagrell and Baraldi, 2019), and as innovations are implemented, they transition toward new ones. In this paper, we aim to investigate the current and emerging actor roles within the application areas of geofencing for freight transport. Therefore, we have developed two research questions:

RQ1. Who are the key actors and what are their roles in developing geofencing?

RQ2. How do actors expect their roles to change when transitioning to the implementation setting, and what are the implications of this for role dynamics?

To investigate the geofencing network, a case study has been conducted. This method allows us to study a number of actors, their roles and interactions in the current developing setting and the expectations for their roles and interaction in the implementation setting. By answering these research questions, we will expand the existing knowledge base on the organization of geofencing, how technological development is enabled through interaction between public and private actors and how to transition from a developing to an implementation setting when multiple actors with different drivers are involved.

The paper is structured as follows. First a theoretical frame of reference is presented. Following is a description of our chosen methodology. Thereafter, the empirical case findings are presented. Finally, a discussion and conclusions are provided, including a number of future research issues.

2. Theoretical frame of reference

2.1 Business markets as networks

We rely on the IMP approach to business markets, which emphasizes business relationships between firms connected in network-like structures (Håkansson *et al.*, 2009; Håkansson and Snehota, 1995). Business relationships are often complex in that they involve several organizations and individuals and have undergone adaptation in the form of investments and joint innovation efforts (Lind and Melander, 2019). The way that business networks change may be decided partly by network conditions and relationships, and partly by the representation and willingness of the involved actors (Guercini and Runfola, 2012). There are many different actors within these networks who interact with each other and influence the network, including customers, suppliers, users, intermediaries, governments and other organizations (Baraldi *et al.*, 2011; Melander and Arvidsson, 2020). Interaction happens between actors across entire networks; it evolves over time and is shaped by previous and ongoing interactions.

Taking an interactive view of business relationships means that it is insufficient to look at just single actors; instead, interactions between actors must be considered (Ford and Håkansson, 2006). Actors are always dependent on other actors in their network; no single actor controls all the necessary resources to operate its business (Gadde *et al.*, 2003; Håkansson *et al.*, 2009). Interaction is also an important aspect of developing new business models (Bankvall *et al.*, 2017; Håkansson and Waluszewski, 2013; Jocevski *et al.*, 2020; Melander and Arvidsson, 2021).

Actors' roles in business networks are commonly understood in relation to their network positions. An actor's network position, according to Mattsson and Johanson (1992), is defined by the exchange relationships it has with other actors. The network position is a consequence of past relationships; it connects unrelated actors and influences the development of future relationships (Mattsson and Johanson, 1992). According to Anderson *et al.* (1998), roles and positions are "inseparable": there are no roles without positions and no positions without roles. In essence, Anderson *et al.* (1998) argue that companies have a position and act in a role. This means that it is important to understand an actor's interpretation of its roles.

There are different ways to describe the roles of actors in business networks. Olsson *et al.* (2013) identify roles in the activity and resource dimensions of networks. The roles they identify in the activity dimension are activity specialization and activity coordination, whereas the roles in the resource dimension are resource provisioning and problem solving. Guercini and Runfola (2015) stress the importance of interaction and highlight that roles are formed through interaction between actors. Over time it is possible to change roles, for example, by taking on new activities or developing resources through interaction with other actors.

2.2 Public–private interaction in business networks

Public–private interaction has received much recent attention in IMP literature (Guercini *et al.*, 2020; Håkansson and Axelsson, 2020; Mattsson and Andersson, 2019; Melander and Arvidsson, 2020; Wagrell and Baraldi, 2019; Waluszewski *et al.*, 2019). The IMP approach stresses the importance of relationships and interactions between actors. However, public procurement has a transactional nature, which limits interaction between private and public actors, as well as innovation (Melander and Arvidsson, 2020; Waluszewski and Wagrell, 2013). However, historically there are several examples of important innovations that have been developed through public procurement. For example, Axelsson and Torvatn (2017) point to the co-development of innovations within the area of electricity and telecoms through the interaction of public and private organizations related to them. Public organizations need to support innovation by sharing knowledge with private organizations, e.g. users and their contexts. However, this type of in-depth interaction is difficult to achieve because of regulatory environments. In a recent study, Mattsson and Andersson (2019) show how digital transformation and public service innovation are intertwined in ongoing processes that affect how actors interact.

Despite the transactional nature of public–private interaction, Munksgaard *et al.* (2017) show how relationships still play an important part in public–private innovation, through which experienced firms use relationships with other actors in the wider public network as a device and asset for overcoming challenges. These firms strategize to embrace the complexity of the public setting, while also working on the technology innovation process. Hence, public–private interactions in the innovation context are complex. This complexity is because of multi-level interactions between private and public organizations as well as within local purchasing organizations (Mattsson and Andersson, 2019). Similar organizational complexity is observed by Guercini *et al.* (2020) in the public health-care system. In their study, they show that the health-care system is highly fragmented and complicated by the different levels involved, i.e. central government (central level), individual regions (regional level) and other local health-care institutions (local level).

Public actors work on multiple levels at various points in time. Hence, public actors need to embrace many different roles (Guercini *et al.*, 2020; Wagrell and Baraldi, 2019). Guercini *et al.* (2020) show that public actors are customers as well as playing a supporting role, while Wagrell and Baraldi (2019) point to public actors having multiple roles, ranging from co-developers and financiers to large-scale users. Munksgaard *et al.* (2017) argue that although public users are near absent in the development of public–private innovation, they still have an important role in providing input to the technology development processes of private firms. Waluszewski *et al.* (2019) argue that in public–private project collaborations, the public side needs to be engaged for innovation to occur. The authors point to the need for organizing the exchange of information and knowledge in the public–private interface. Public organizations also need to initiate and handle dynamics in the interface over time, ensuring an active interaction process involving both public and private actors.

2.3 Roles in innovation networks

Innovation requires new combinations of resources to identify new solutions (Cantù *et al.*, 2012). These resources are controlled by different actors, whereas innovation occurs through the interaction between actors (Håkansson and Waluszewski, 2007). However, innovation is about more than just coming up with new solutions; it also includes the integration and commercialization of those solutions (West and Bogers, 2014). A core issue in innovation is adaptability and how a solution can be integrated in business operations and create value when used in a specific context (West and Bogers, 2014). New solutions are not used in isolation and have to interact with existing knowledge, activities and technical solutions within organizations. New solutions, being the result of resource combinations, may require further combination or adaptation to fit with established resources or services. Furthermore, new solutions have to fit with the needs of users and society. Hence, innovation is tightly connected to the actors within the network, because it is they who conceive, activate and use the new solutions foremost (Cantù *et al.*, 2012). An innovation process can include multiple actors ranging from customers, suppliers, distributors, regulators and academia. Hence, there are many different interactions

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occurring simultaneously that can result in value for various actors.

The actors within an innovation process can have different roles depending on their input or output. *Intermediaries* are mentioned by Howells (2006) as central to innovation processes as they set research agendas, link actors and facilitate information exchange between these actors. These intermediaries can be compared to what Hurmelinna-Laukkanen and Nätti (2018) define as orchestrators in innovative networks: organizations that can have different roles, such as initiating, coordinating and promoting innovation processes. Makarainen-Suni (2008) mentions four role categories in innovative networks: *users or consumers*, *enablers* (cities, municipalities, public funding), *utilizers* (companies, organizations) and *service providers/developers* (universities, research institutions). In their analysis of 26 living labs, Nyström *et al.* (2014) identify 17 different roles that organizations and individuals can play, including *coordinator*, *service and product developer*, *resource enabler*, *integrator* and *contributor*. There is also evidence that actors can hold several different roles simultaneously within these networks and that the roles change with the network (Nyström *et al.*, 2014). Actors entering or exiting in new stages of the innovation process change the dynamics of the network. One such example is that users are more involved in the early stages of an innovation process and become less involved toward commercialization (Nyström *et al.*, 2014). As actors can have multiple and changing roles during innovation processes, going from the transition from concept to commercialization could imply further complications for the adaptation and integration of innovations into the existing activities and technical solutions of organizations.

3. Methodology

To study the industrial network within geofencing applications for freight transport, this study relies on a case study method. Case studies are suitable for understanding and analyzing the complexity of networks, links between actors and the development of network changes over time (Easton, 1995; Halinen and Törnroos, 2005). We chose to study geofencing in Sweden as it is a leading country in the development of this technology, as well as its implementation in freight-related contexts. The technology has been tested for different applications in several innovation projects, mainly in the cities of Gothenburg and Stockholm. Furthermore, the Swedish ministry of infrastructure has issued two governmental assignments to investigate geofencing and how it could be incorporated into legal frameworks in Sweden. Because of these circumstances, the Swedish case is currently most rewarding when looking to study networks, actor interactions and activities related to the geofencing applications for freight transport in urban and public–private settings.

Data collection has mainly been done through semi-structured interviews based on an interview guide developed in coherence with theoretical themes. The interview guide focused on challenges in the transport system; perspectives on use and the value of geofencing; interactions between actors in the development of geofencing; roles for different actors in current and future settings; and business models. Respondents were sampled from a network of organizations participating in freight-related projects involving the use of geofencing and representatives working in freight planning. To be more specific, the identification and selection of respondents for the study was mainly done through the ongoing "Geofencing research and innovation program" that was initiated in 2018 in Sweden. In this innovation program, both public and private organizations take part to establish collaborative formats to develop and introduce geofencing as a tool for traffic management. Connected to this program are several ongoing freight-related projects to develop, test and evaluate different geofencing applications, mainly in relation to traffic safety and the environment. Hence, knowledgeable respondents from multiple organizations participating in these networks were selected to be interviewed in our study. Furthermore, the respondents were given the opportunity to name other people who could be of interest to interview, resulting in a number of extra interviews with people who were more knowledgeable within the organization or externally.

A total of 18 semi-structured interviews were conducted with 26 unique respondents from both public and private organizations who were either involved in freight-related projects for the development of geofencing or in strategic positions for freight transport planning and development as well as service development and distribution. In some interviews, more than one respondent from an individual organization participated, as shown in Table 1. Because of the circumstances of the Covid-19 pandemic, the interviews were conducted on digital platforms between December 2020 and June 2021. All interviews were recorded and transcribed. Additional data has been collected, consisting of observations from various workshops, meetings and seminars that discuss geofencing in relation to urban freight transport. Secondary data consists of official documents related to geofencing projects in Sweden.

The data analysis consisted of coding the transcripts thematically to map actors and their interactions in different settings using theoretical concepts. The transcripts were coded and analyzed throughout the data collection. First-order coding was empirically driven (Gioia *et al.*, 2013), with labels related to drivers and motivations, barriers to development, implementing and participating in geofencing activities, roles and expectations. Data was structured in mega matrices (Miles and Huberman, 1984) and we started our second-order coding by grouping data into theoretically driven concepts based on IMP constructs such as actors and their roles, related activities, resources and interactions.

We structured the data using a dual-time perspective:

- the developing setting; and
- the implementation setting.

The developing setting refers to the development of technology, discovering use areas, identifying business models and involving relevant actors. In complex networks, the developing setting requires interorganizational collaboration, which implies a shift from firm-centric innovation to network-centric innovation (Coughlan, 2012). The implementation setting refers to the stage in which technology is integrated into established systems and operations (Biggemann *et al.*, 2013). The empirical data on roles in the geofencing network in relation to the developing and implementation settings has been analyzed with existing literature on roles in innovation

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Table 1 Type of organizations and participants in interview study

Abbreviation and respondent's role	Organization	Experience in respective field of expertise (years)	Duration of interview (min)
R1 – Project manager ITS/traffic digitalization	Public authority (local)	5	60
R2 – Strategist in traffic development	Public authority (local)	15	55
R3 – Urban freight strategist	Public authority (local)	4	53
R4 – Smart city coordinator	Public owned companies	2	59
R5 – Urban freight strategist	Public authority (local)	2	52
R6 – Urban freight strategist	Public authority (local)	1	52
R7 – CTO	Transport service provider	14	58
R8 – Senior manager in research and innovation	Vehicle manufacturer	7	75
R9 – Senior advisor commercial transports	Public authority (local)	13	80
R10 – Business unit manager fleet management	Third-party service provider and map service provider	4	60
R11 – Product manager fleet management	Third-party service provider and map service provider	3	60
R12 – Business consultant for projects on connected vehicles and business development	Vehicle manufacturer	5	60
R13 – Technical consultants for projects on connected vehicles and business development	Vehicle manufacturer	5	60
R14 – Sales Nordic division toward vehicle manufacturers	Third-party service provider and map service provider	30	78
R15 – Head of development geofencing and ITS	Public authority (national)	3	75
R16 – Market/sales of geofence service	Vehicle manufacturer	6	35
R17 – Technical development ITS	Vehicle manufacturer	9	31
R18 – Technical development ITS	Vehicle manufacturer	6	31
R19 – Product planning	Vehicle manufacturer	4	56
R20 – Fleet management service owner	Vehicle manufacturer	–	56
R21 – Product planning	Vehicle manufacturer	–	56
R22 – System engineer	Vehicle manufacturer	20	56
R23 – After-sales manager	Vehicle manufacturer	2	55
R24 – Senior project manager mobility research and innovation	Third-party service provider and map service provider	3	82
R25 – Head of unit road user	Public authority (national)	4	56
R26 – Project manager/analysist traffic rules	Public authority (national)	–	56

contexts. Data was also structured by the organizations' own view on their role and expectations as well as those of other actors in the network. We grouped actors and labeled their distinctive roles (e.g. the label "intermediaries" consisted of academic actors and project managers). These labels are based on the theory of innovation networks (Howells, 2006) and on empirical data (e.g. intermediaries).

4. Case findings

4.1 Geofencing in Sweden

In Sweden, discussions on using geofencing as a tool to control or manage traffic started after the terrorist attack in Stockholm 2017, when the Swedish Government issued an assignment to the Swedish Transport Administration to test geofence as a tool to increase traffic safety and reduce the risk of vehicle ramming. This resulted in a collaboration between the Swedish transport administration, the cities of Stockholm and Gothenburg and three Swedish vehicle manufacturers to test geofencing applications and investigate how the technology could be developed and introduced as a measure to reduce transport-related accidents. The collaboration has resulted in numerous initiatives and projects in public–private contexts in which authorities, vehicle manufacturers, service providers and service users work together to develop and deploy the technology. These collaborations usually occur within different projects funded by national agencies. Furthermore, a Swedish research and innovation program for geofencing was established in 2018 to encourage collaboration between involved actors and distinguish areas that need development for the further implementation of geofencing in traffic and transport management. Different projects and pilots focus on different use cases and applications, not only for freight but also micro-mobility, public transport and private vehicles. The applications for the various projects focus foremost on speed regulation of vehicles, propulsion adjustment for hybrid vehicles and access restrictions.

For instance, within the Eccentric project, a pilot was run using geofencing to ensure HGVs used an electric powertrain during off-peak deliveries to restaurants within a zone defined by the city authorities. Another project, Smart urban traffic

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zones, is running a pilot in which the speed of HGVs is adjusted in relation to the number of vulnerable road users in an area, and another in which permits are granted to extra heavy vehicles as long as they can ensure their speed is reduced in certain zones in central Stockholm. In Gothenburg, there have been pilots for dynamic environmental zones that can be alternated depending on emissions and traffic conditions.

4.2 Geofencing from public and private perspectives

Depending on the application, perspectives on geofencing differ between public and private organizations when it comes to their responsibilities, roles, operations and the main areas of use for the technology. Among public organizations, the common view is that geofencing can be a technology to "control connected vehicles", "distribute digital traffic regulations" or, as stated by Respondent 15, "provide conditions for OEMs to make it difficult or impossible to violate traffic rules, regulations [. . .] [and] give road authorities new possibilities to manage traffic."

Private organizations view geofencing somewhat differently. Applications that use geofencing to enable authorities to impose regulations that make it difficult or impossible to violate traffic rules or regulations are less relevant in this case. However, many private organizations in the study have developed and deployed various geofencing services of a simpler nature; for instance, fleet management services that help customers to keep track of vehicles and ensure they follow pre-determined routes or simplify vehicle maintenance or toll payments. One vehicle manufacturer has developed and deployed a service for HGVs that allows customers to design geofences for certain speed limits or zones that only allow electric propulsion. Applications that allow road operators can define geofences, and the rules within them are only available in small-scale pilot projects. Some private organizations see a possible future that is aligned with some public organizations, in which road authorities can design and operate geofences that are distributed to vehicles. Others see road authorities having a similar role as today, to design and regulate road usage.

From both perspectives, it is assumed that geofencing will operate in two main ways in the context of public–private interaction. The first is using geofencing to enforce controls such that vehicle behavior automatically changes upon entering or exiting a pre-defined geofence. The geofence and associated rules can be defined by a service provider or other trusted actors, for instance, road authorities or customers. The second is using geofencing to provide information such that a driver receives information through an interface when entering or exiting a pre-defined geofence. While there is no action or change in the vehicle, the driver can choose whether to act on the information. Table 2 provides an overview of the two main use areas for geofencing and examples from the study of possible applications and their implications.

4.3 Motivations for geofencing development

All respondents identify benefits of geofencing for transport-related applications. For the public authorities, its main value lies in the social and environmental benefits of traffic safety and lower emissions:

> [. . .] the main point is how you want a city to be, which is clean, silent, secure, accessible, and such things (R2).

> You should create quiet and slow vehicles and there I think geofencing will be very central, and not only for trucks and buses but also for cars I would like to argue (R9).

> Geofencing is an enabler for increased traffic safety and to make it healthier and more pleasant to be in cities (R1).

So, for public authorities, the main objective for geofencing is to ensure the interests and well-being of inhabitants, which is within their public mission.

Private organizations, on the other hand, have other interests to consider. Their focus is the benefits to their customers, including lower maintenance costs, reduced fuel consumption and longer up-times, which in many cases is the reason for developing geofencing:

> What is going on in the near horizon is still mainly connected to our customers, those who operate the vehicles, and what needs they have in the first place. What is a little further away [in the future] is what we work with, as in ecosystems and explore other needs that are outside it, such as needs that cities and authorities and other customers, and customers' customers and others have. It can be the same functionality, but the services and what we offer there are a little further away, you could say. One reason why we are involved in this geofencing project, of course, is to understand that better (R8).

This view is supported by other service providers who see little or in some cases no demand for the kind of geofencing services that ensure freight vehicles follow set traffic rules. However, several respondents state that the demand could increase, in which case they need to be ready to deploy such services:

Table 2 Area of use, applications and illustrations of geofencing in Sweden

Areas of use	Applications	Examples from public and/or private actors
Control	Control speed, propulsion or access of vehicle in specified areas	Public actors • control connected vehicles • manage traffic • provide conditions or geofences to make it difficult or impossible to violate traffic rules and regulations Private actors • design and provide geofencing zones based on customers' or other trusted actors' demands/requests for speed limits or propulsion type • provide tools for customers to design geofences with a certain speed or zones allowing only electric propulsion
Inform	Inform drivers of speed limits, propulsion requirements or other upcoming restrictions in specified areas	Public actors • distribute digital traffic regulations that drivers need to act on Private actors • distribute information to vehicles and drivers

> At the moment no one really knows what it [geofencing] is on the market, but in a couple of years it may be an established solution and then we must have kept up with that development (R11).

This statement is backed up by another respondent who states that:

> The customers do not always see the possibilities with the new technologies, and that it is up to the service provider to understand the customer's needs and come up with solutions (R21).

Many also acknowledge a growing trend of cities implementing various zones, mostly in relation to emissions. Geofencing could be a technology to promote low-emission vehicles if the market share of electric-hybrid HGVs increases. A couple of service providers see a positive of this trend being tougher requirements from authorities accelerating the transition toward greener vehicles.

It is also acknowledged by respondents in public and private organizations that there are conflicting drivers at hand. As a respondent from a private organization puts it:

> [. . .] road authorities have certain policy goals, but they don't necessarily always match with the interests of our drivers [. . .] So, there are a lot of considerations there and it is not always very easy to talk to the road authorities and make them understand our part of it, because it is very clear to them that 'it would be nice if you [the service provider] can send people a certain way', but we [as the service provider] have, of course, the interests of our users and customers. In the same way the OEMs always have the end-user in mind (R24).

4.4 Perspectives on roles for developing geofencing

Most respondents indicate that the roles of different actors are not clearly stated and that they change as geofencing is introduced. As stated by a representative from a service provider:

> One reason why we are involved in various projects is to explore what our role can be. I emphasize that question when it comes to geofencing as an important part is to explore what our role is (R8).

While some state that public organizations will have a more active role in setting regulations and controlling vehicle movement by designing geofences, others suggest that there will be little interference from public organizations and agencies. The latter group imply that public organizations will provide traffic rules digitally, around which private organizations will design geofencing services.

Actors involved in the development of geofencing have different dimensions of interests that can influence their role or activities. While service providers must relate to international markets, public authorities are more concerned with national and local interests. Most respondents realize the importance of collaborating with international agencies to ensure harmonized measures for geofencing, as stated by one respondent:

> [. . .] to see how this public private cooperation goes, that is still not so clear, especially due to issues like scalability and how [. . .] we're a global provider, we can of course not engage with each city big or small. I mean, [with] the big ones it is not so difficult maybe but [. . .] So, these are things that still need to be solved and how to make that scalable, how to standardize information, how to make it easily accessible (R24).

Furthermore, significant development currently takes place in small-scale research and innovation projects that depend on collaboration. These are usually enabled by governmental funding from different national or international agencies with specific agendas. Many, including public organizations, realize the importance of collaborating with international agencies to ensure harmonized measures for geofencing. In some cases, collaboration between competitors is also eminent:

> And we're actually working with our competitors together because they have the same [. . .] [. . .] [. . .] but we are actually working together to make this more accessible because what we build on top of that or other products we build on top of that information is proprietary. But we have the same interest to get this information in a form that is actually harmonized and standardized that we can all use (R24).

Other actors mentioned in the study are transport buyers, who have a significant influence on transport through procurement, and insurance companies, who can offer lower prices for safer vehicles. IT service providers are also mentioned, who, depending on the application area, provide technical solutions for data exchange between the involved actors and provide software for designing and distributing geofences to private and public actors.

4.5 Summary: developing geofencing

The actors, resources and activities, interactions and drivers for geofencing development are summarized in Table 3.

Currently, the positions of the different actors within the network are in line with their traditional missions. Public authorities are responsible for planning, building and maintaining physical infrastructure and setting the rules that are to be applied to this infrastructure. In contrast, private organizations function to create and distribute products or services that make use of the infrastructure or make operation more efficient for infrastructure users. However, in developing geofencing, these network positions or responsibilities can change, thus influencing the roles of actors.

5. Analysis

5.1 Actor roles involved in developing geofencing

Based on the case study above and literature on roles in innovation networks, we identify five dominant categories of actor roles in the development of geofencing: *enablers*, *service providers*, *regulators*, *users* and *intermediaries/orchestrators*. The category *regulators* is not mentioned in previous literature regarding roles in innovation networks. However, as policy and regulation strictly affect innovation (Butenko and Larouche, 2015), and regulation and standardization was frequently mentioned among the respondents in the study, *regulators* seems too important a category of actor role in the development of geofencing to exclude. *Regulators*, such as the EU and UN, can influence development when it comes to standardization, data security, integrity and basic rights.

The most dominant roles in the current development setting are *enablers* and *service providers*. Most respondents, both from public and private organizations, identify public organizations as *enablers*, meaning that they provide necessary resources and funding for the development and implementation of geofencing. In some cases, they are also identified as the designers and distributors of geofences. Depending on application, the *enablers* are also responsible for assuring that necessary and quality-assured data is available to create geofences as well as adapting the physical infrastructure to enable certain geofencing applications. *Service providers (geofencing)* are actors that develop and commercialize geofencing services. These can be vehicle manufacturers or third-party service providers that install hardware in vehicles to

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Table 3 Actors, resources, activities, interactions and drivers for geofencing

Actor	Resources and activities	Interaction with	Drivers
Public organizations			
Local road authority	Introduce digital tools for data sharing and check data quality Policy implementation for roads in cities	Road authorities (national) Vehicle manufacturers and third-party service providers IT service providers Freight transport operators (through procurements and policy implementation) Project partners	Safety and well-being of citizens
National road authority	Share data on traffic and infrastructure Introduce digital tools for data sharing and check data quality Policy implementation for state-owned roads	Road authorities (local) Regulating agencies (national and international) Vehicle manufacturers IT service providers Freight transport operators (through procurements and policy implementation) Project partners	Safety and well-being of citizens Facilitate market-driven technology advancement
Funding agencies (national and international)	Financial support for research and innovation	Project partners	Governmental goals and objectives in relations to sustainability and market development
Regulating agencies (national and international)	Develop regulations and standards	Local and national road authorities	Safety and well-being of citizens Facilitate market-driven technology advancement
Private organizations			
Vehicle manufacturers	Develop and introduce geofencing service Define business models Develop APIs/interfaces for geofencing applications	Local and national road authorities Customers/users (freight transport operators) Map service providers Regulating agencies (national and international) Project partners	Market and technology Create services that increase efficiency or reduce operational costs for customers
Third-party service providers	Develop and introduce geofencing service, often retrofit solutions Define business models Develop APIs/interfaces for geofencing applications	Customers/users (freight transport operators) Local road authorities Map service provider Project partners	Market and technology Create services that increase efficiency or reduce costs for customers
Mapping-service providers	Provide map data services, mainly for private actors	Vehicle manufacturers Some cases public road authorities	Market and technology
IT service providers	Hardware and software for data exchange and geofencing designing tools	Vehicle manufacturers Public road authorities (local and national) Project partners	Market and technology
Freight transport operators	Provide freight transport services Buy or lease freight vehicles Defines geofences in tool provided by service provider	Shippers/transport buyers Vehicle manufacturers Third-party service providers Project partners	Reduced costs of operation and better work environment for drivers
Shippers/transport buyers	Set requirements on transport quality in procurements	Freight transport operators	Ensure quality of transport of their goods
Insurance companies	Create incentives for more safe vehicles and careful driving	Freight transport operators	Market incentives Increase road safety
Non-categorized organizations			
Academic and research centers	Create knowledge, models, simulations, evaluations of geofencing	Project partners	Knowledge creation
Project managers	Initiate, manage and facilitate various geofencing projects	Project partners Funding agencies (national and international)	Innovation

Note: API = application programming interface

enable geofencing applications. There are also service providers who support the development of geofencing with necessary software or hardware to create and distribute geofences; for instance, mapping-service providers or IT/telecom businesses that can provide services to vehicle manufacturers, third-party service providers and road authorities. *Users* are actors who pay for and use geofencing services in some way, mainly transport operators and public authorities. They are, to some extent, involved in the development of geofencing by providing input on user interfaces and functionality. Lastly, as the technology is mostly being tested and evaluated through small-scale projects, there is a need for *intermediaries/orchestrators* in the current network. These are researchers who evaluate and generate knowledge on future implementation strategies, as well as project managers who coordinate pilot projects and living labs, where actors cooperate in developing technology.

The identified actor roles and their interactions in the developing of geofencing are shown in Figure 1. The interactions can consist of activities and resource exchange, such as data, knowledge or services.

5.2 Expectations for future roles in geofencing implementation

With regard to the expectations for future actor roles in the implementation setting, new structures in the network need to appear. Actor roles are expected to change and actors are expected to enter and exit the network. Examples of actors that are likely to exit the network are *regulators* and *intermediaries/orchestrators*, who it is not considered will play a crucial role when geofencing is implemented. In the developing setting, *regulators* and funding agencies have the role of assisting and stimulating the development process of geofencing by providing funding and setting technical standards and international regulations. Once geofencing services are implemented, standards and regulations will already be in place. The same is true of *intermediaries/orchestrators*, who are needed foremost in the developing setting to initiate and evaluate projects.

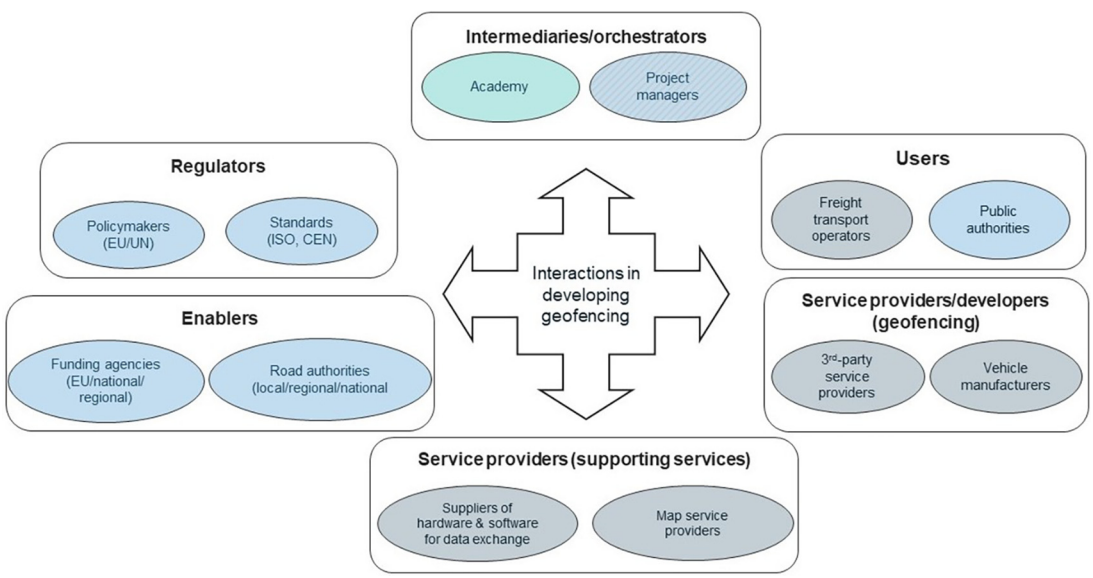
Instead, new actors are expected to have central roles in the geofencing network, examples of which are transport buyers and insurance companies. The study implies that these actors, through different measures, can encourage users to buy and use geofencing services. Transport buyers can include demands in procurement processes to ensure transport quality and insurance companies could reduce costs for vehicles with higher safety standards enabled by geofencing. It is also assumed that public organizations will play a greater role here as they procure vast transport services and commonly set strict demand on vehicles and companies carrying out transport on behalf of cities. City authorities thus take on a dual role, both as a user of geofencing services and as a promoter of geofencing among transport service providers.

For the actors categorized in the developing setting as *enablers*, there are different expectations on future roles, depending on the application of geofencing. Some expect public authorities to take on a more active role in controlling traffic with geofencing. This implies activities to create, regulate, control and distribute geofences. However, not everyone within the network shares this expectation, and some expect authorities to merely be a source of data which service providers can use to create and manage geofences. Depending on the outcome, authorities may take on one of two different roles:

1 enabling new services by digitalizing data and policies or
2 designing and distributing geofences to have a more direct impact on vehicle restrictions in defined areas.

Service providers have a similar role when studying the current developing setting, in which they develop and sell services. Depending on the roles authorities take, geofencing will either be incorporated as an add-on for existing services or made an obligatory feature in new vehicles. Hence, service providers are expected to cope with adapting to the development of legal frameworks and the roles of enablers.

Figure 1 Business interaction and actors involved in developing geofencing (blue: public org; gray: private org; green: academic; blue/gray: public or private actor)



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6. Discussion

In the current setting, in which geofencing for traffic management is still under development, actors are in the process of identifying their roles, especially public organizations. Role dynamics with respect to this development is discussed below.

6.1 Public–private dynamics in geofencing development

Geofencing development is dependent on public–private collaboration, which in most contexts is difficult to manage. This is often because of differences in perspectives and drivers (Lind, 2015; Waluszewski *et al.*, 2019). This is also the case for geofencing; ultimately the private sector is dependent on sales of products and services, while the public sector must serve public interest. However, despite the differences in drivers, there is a collective interest in the development of geofencing, as it contributes to individual objectives, as well as the overarching objective of increasing sustainability in urban environments. This creates a co-dependance between public and private actors in the development of geofencing. In addition, once implemented, there will still be co-dependence as public actors will need to provide sufficient data for geofencing services to be built around, or design, operate and distribute geofences themselves. Hence, actors are dependent on the provision of data and the development of the digital technologies for geofencing. Ultimately, digitalization affects how these public–private actors interact, which is in line with previous research on digitalization and public–private interaction (Mattsson and Andersson, 2019).

However, there are some uncertainties as to how public and private actors will interact. On the one hand, an active role for the public actors would require them to create, regulate, control and distribute geofences. On the other, a more inactive role would limit them to similar tasks and responsibilities they already have, namely, making infrastructure and traffic-related data digitally available, which other actors can use to create and manage geofences. Of course, public actors can have different roles on different levels (Guercini *et al.*, 2020; Mattsson and Andersson, 2019). They could play an active role at a national level, setting regulations and controlling functions, and an inactive role at a regional or city level, providing data for private users. Similarly, public actors can take on multiple roles (Guercini *et al.*, 2020; Wagrell and Baraldi, 2019); for example, one public organization may have a department for procuring transport that uses geofencing (limited interaction), another for providing data (limited interaction) and another for defining and distributing geofences (implying more interaction). Hence, the roles of public organizations in the development and implementation of new technology are complex and include different levels of interaction with private actors within the network.

6.2 Role dynamics in geofencing development and implementation

Actors make decisions in relation to their own expectations and those of other actors in the network (Anderson *et al.*, 1998). In the case of geofencing, much of the technology's development occurs through various research and innovation projects, within which discussions and activities set expectations for actors' roles and positions in the network based on resource allocation and resource combining, as well as future activities. Hence, actors' current and future roles are formed through these projects.

Furthermore, the interactions in projects are essential for overcoming potential challenges in the public–private setting (Munksgaard *et al.*, 2017). For all projects mentioned in the study, public and private organizations collaborate in development settings, trying to identify useful applications and develop technical and operational processes for them. It is also important for actors to understand each other's perspectives and operations, especially in the case of public interaction, which occurs on many different levels (Mattsson and Andersson, 2019). This is also the case for geofencing; public sector activities involve people from legal departments, technical departments, strategic and planning departments and operations, both on a local and a national level. However, in the research and innovation projects, public organizations are not as closely bound to public procurement, and their participation is facilitated by funding agencies. Public organizations thus have more freedom in exploring, testing, and identifying their potential future roles in this setting. This confirms the statement that public actors are active on multiple levels at various points in time and embrace many different roles (Guercini *et al.*, 2020; Wagrell and Baraldi, 2019). Furthermore, as mentioned in the results, one of the most important aspects of participating in these temporary innovation projects is the exchange of information and knowledge between public and private actors, as per the study by Waluszewski *et al.* (2019).

The geofencing network needs to be dynamic, given the expectation that actors and their interactions will differ quite substantially from the development setting and expected future implementations. Service providers, enablers and users are involved in both settings but could potentially occupy different roles between the two. This is especially true for enablers who are expected to take on a role to which they are currently unaccustomed. Understanding one's role and adapting to it requires integration and adaptation between existing and new resources within an organization. New routines, systems, competences and interaction between different departments will likely be needed, increasing the challenge of implementation. Meanwhile, service providers are expected to occupy roles with which they are more accustomed, either as service providers acting on market incentives or as implementers of standardized and regulated services. They are thus expected to adapt their role in line with legal developments and in response to enablers and users. In contrast, users will experience a more linear role development; in the development setting, they provide input on interfaces, user experience and user effects, and during implementation, they become service users. The adaptation for service providers and users to their new roles is potentially easier as there are fewer new resources to integrate. It thus seems likely that resource development will form the base for emerging roles, in line with Olsson *et al.* (2013) and Aaboen *et al.* (2016). Resources will have an impact on actors' roles as these affect what an actor can do and impose on other actors. Resource availability also creates expectations of actors. Service providers see possibilities to create services based on data provided by enablers, while enablers see new data and data-sharing resources as opportunities to enforce new

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regulations in line with overall drivers of more sustainable urban environments.

Activities also influence the role dynamics of different actors. In the development setting, actors collaborate on projects and initiatives for a shared purpose. These activities are expected to change when geofencing is implemented on a larger scale, which will also impact the expected roles of actors. However, at this point, it seems less likely that activities will form the base of actor roles in geofencing because the responsibilities for certain activities, and thus the impact on the role identification process, have yet to be determined.

Another implicating factor is that geofencing development occurs on different levels within organizations, for example, across departments or divisions, as well as at different external levels for different institutions. This also affects the role of the dynamics of the network, as the departments that are involved in the current development setting in various projects are in many instances not the ones that will be involved in the later operation of geofencing, within both public and private sectors. The technology needs to be adapted by different departments within organizations as well as at local, national and to some extent international levels with regard to legal requirements. Similar complexities are observed by Guercini *et al.* (2020) and Mattsson and Andersson (2019). This means that an actor may express responsibility or take on a specific role within a project that is no longer accepted or endorsed when other departments or institutions become involved.

Hence, from our study, we have observed three types of general role developments, within a specific setting as well as in the adaptation from one setting to another (in our case from an development to an implementation setting). The first is a reliance on a role in the current setting, "business-as-usual," referring to there being limited to no change in an actor's role. The second is a radical change in resources and performed activities, a "path-breaking" role development; for example, a new actor entering the network, an old actor exiting the network or an actor taking on a new role in the network. As discussed above, enablers may see their roles develop in either of these two directions. The third type, "incremental" change, implies the development of a role from one setting to another, with the actor adapting the role in response to increased knowledge and the roles assumed by other actors. Incremental change may be the route forward for service providers; their roles will depend on those that other actors adopt and the development of legal frameworks.

7. Conclusions

This paper aims to investigate the emerging actor roles in industrial networks of geofencing applications for urban freight transport. To succeed with new and difficult projects spanning many different areas and involving the development and implementation of advanced technology, many issues need to be resolved, such as legal issues; local, national and international regulations; and digitalization and developing business models that involve many different kinds of actors; hence, there is a need for broad collaboration platforms through which many disparate actors can contribute their expertise. Yet, actors from the development phase may change in implementation stages. Our study has identified several key actors in the geofencing network from both public and private organizations and categorized their roles in the development of geofencing. Within these roles, actors perform a number of activities to enable the development of geofencing; for example, developing technology or policies and exchanging services, data and knowledge. In addition, we have identified close interactions between public and private actors in the network, although perspectives and drivers for geofencing development may differ between these categories.

The actors involved have a number of motivations for participating in the network, including in connection with sustainable transport policy and market incentives. Geofencing technology thus appeals to the interests of the identified actor categories by potentially enabling cities to fulfill certain sustainability goals and allow the market to provide more cost-efficient transport services. The study also illustrates the complexities of development and that the involvement of multiple actors may not mean a straightforward implementation. There are potential barriers involved in implementing new technologies; for instance, as seen in this study, public actors will eventually set the regulations for these innovations and, despite involvement in their development, may hinder usage. The more actors and complex organizations involved, the vaguer the expectations of future roles and more difficult the adaption to new roles through technology integration and use.

7.1 Theoretical contributions

This study contributes to the field of IMP research by focusing on actors and interactions in the context of public–private collaboration. We build on previous studies in the public–private setting by providing a new context for public–private collaboration in innovation. Our detailed empirical case shows the complexity of multi-actor involvement in the development of digital technology for the transport system. Previous research on public–private actors and roles has been conducted in empirical contexts such as health care, education, defense and construction (Guercini *et al.*, 2020; Mattsson and Andersson, 2019; Melander and Arvidsson, 2020; Wagrell and Baraldi, 2019; Waluszewski *et al.*, 2019). We provide another context: the digitalization of the transport system, and specifically, the development and implementation of geofencing. Interactions between public and private actors in innovation networks depend on the roles these organizations occupy. Public actors have extensive interactions with private actors as enablers and more limited interactions as influencers. Hence, in the development setting, public actors are less restrained in their interaction with private actors in comparison to when acting as procurers of products or services.

Digitalization in the context of transport systems relies upon several crucial factors, such as multi-actor collaboration and new business models in the context of public–private interaction (Cooper *et al.*, 2019; Leviäkangas and Öörni, 2020; Whittle *et al.*, 2019; Zlocki *et al.*, 2019). By illustrating the complexities of developing and implementing geofencing, this study provides additional details on actor involvement and changes in role dynamics in the transition between these settings.

Our study also contributes to the field of different roles in public–private collaboration settings. The paper explores role

dynamics within the current setting (such as a development setting) and the transition between settings (such as when transitioning from development to implementation). Within the current setting, we found different roles on different levels, as discussed by Guercini *et al.* (2020) and Mattsson and Andersson (2019). In our study, some private actors have a global presence, which would result in multiple interfaces in different markets. These interfaces are not limited to countries, but could result in interfaces at the regional as well as local level. Here, previous knowledge gained from one region may not be useful in another (Sundquist and Melander, 2020; Wagrell and Baraldi, 2019). Hence, there is a desire for standardization in implementing geofencing so that actors can make use of existing developments. Actors' roles may be limited to path-breaking changes in the transition between settings (such as development to implementation). In new settings, new actors enter the network, existing actors exit the network and roles may change dramatically. Public actors may also occupy multiple roles that are coexistent rather than separate (Guercini *et al.*, 2020). As roles change, so do interactions. However, even when roles remain more or less the same, interaction changes over time as new knowledge is gained (Mattsson and Andersson, 2019).

7.2 Managerial and policy implications

Our study points to a number of managerial implications. First, the study highlights the transition from firm-centric to network-centric innovation and its implications for roles. Organizations participating in public–private innovation networks need to be aware of the complexity of public organizations and their multiple roles. Roles may vary between departments within public organizations, change as innovation projects progress and vary between levels (such as national, regional or city). Hence, managers may need to develop relationships with public organizations on multiple levels. Second, expectations on roles of public and private organizations may vary as these may be undefined or change throughout the project. Here, interaction can facilitate and bridge some of these discrepancies. Through interaction, managers can reach an understanding of other actors' capacities and limitations in regard to the roles they aspire to occupy.

Our study also points to some policy implications. One such implication relates to the transition from small-scale testing of new technology to large-scale implementation. In small-scale projects, it is possible to overcome the usual boundaries of public procurement and standardization. However, when scaling up and implementing novel technologies, consideration must be given to policies, standards and governmental procedure. Current policies can ultimately hinder the implementation of certain technologies that rely on multi-actor collaboration and hinder actors in taking on an expected role because of interorganizational and internal discrepancies. These are issues related to innovation procurement, public–private partnership and national and international regulations. Setting standards should ideally be a global endeavor involving public and private actors. A second policy implication relates to data exchange. Despite the potential of new technology and expectations of taking on a specific role in developing networks, much depends on legal requirements, technical possibilities and the security of data sharing. There is a need to revise policies to enable data sharing among multiple actors while simultaneously ensuring the (in this case, often the driver's) integrity of individuals.

7.3 Limitations and future research

Finally, our study has a number of limitations. We have studied the Swedish context, despite the fact that service providers often act on global markets. However, as Sweden is at the forefront of developing geofencing, it is a suitable geographical context to study. Furthermore, as geofencing is still in its infancy in public–private applications, activities and roles are expected to change as the technology advances. Therefore, it could be beneficial to investigate potential future scenarios. In public organizations, there are several different departments that need to collaborate to incorporate geofencing in operations, where "actors within actors" could be further explored. There are also issues related to network settings, including how to move from the development setting to the implementation setting, as geofencing becomes a part of transport and traffic management. Hence, investigations into the transition from temporary projects to permanent structures are warranted. The transport system is experiencing change because of digitalization and the new interactions it enables, but so are other public settings, in which significant change will occur in the coming years. In addition, network-centric innovation will potentially rely on a network-embedded business model (Bankvall *et al.*, 2017). These forms of business models will be important topics for further research.

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