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Sensors securing sustainable digital urban logistics—A practitioner's perspective

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The transport of goods, equipment and waste to, from, in and through urban areas (urban logistics) are essential for the economic vitality of the city but at the same time make urban environmental and social targets more difficult to achieve The European Green Deal and the UN Sustainability Goals also challenge the ways of addressing planning and management. At the same time Covid 19 has led to new challenges for urban logistics together with changes in consumer purchasing and travel patterns. Digitalisation offers new ways of collecting data and providing input to planning and modelling of urban logistics that might alleviate these challenges. This article addresses how digitalisation and especially sensors can contribute to new forms of data for analysis and play a role in developing sustainable digital urban logistics measures and plans through data collection and sharing. The research contains empirical insights from a survey and workshop in Norway. The results from the survey show that sensors are the digital solution that practitioners see as most useful for urban transport. This is supported by results from the workshop supporting a sensor scenario. When it comes to the digitalisation process, the practitioners expect that the different levels of government will facilitate digitalisation of urban logistics and most practitioners have the opinion that all levels of government should do more to facilitate new solutions Testing should take place as collaboration between private and public actors. Due to Covid 19 the government level is seen to have an important role for exchange of information and advice, and for giving economic incentives and support, rather than providing law and regulatory changes or the reorganisation of public services. The local level is considered to have an especially important role for digitalisation including data for modelling, planning or public procurement procedures. The article addresses these questions by reference to the partnerships for freight transport in London and Gothenburg. This article adds insights for planning practitioners into how sensors will challenge as well as provide new possibilities, to suggest new paths for planning and modelling urban logistics and an amplified role for freight partnerships.

KEYWORDS
freight and urban logistics, transitions, big data, data sharing, sensors, network governance, freight partnerships

1 Introduction

The European Green Deal and UN Sustainability Goals have established a range of targets for sustainability at the European and international level (United Nations, 2015; European Commission, 2019). Both have developed indicators and set ambitious sustainability goals that needs new knowledge and sets new standards for collecting data. The UN sustainability goals comes with a set of indicators both on resilient infrastructure (goal 9) and urban development (goal 11) where sensors and sensor data could provide direct knowledge for the measurement of indicators or indirectly as part of policy making and participation. In the European union, the European Green Deal goes beyond the goals from the Paris agreement and aims at reducing greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels (European Commission, 2019). The European Green Deal also includes several measures with wide-reaching implications for both the public and private sector including how planners and other practitioners collect data and model urban logistics. But it is not only a question of data and modelling. Urban logistics needs to change in order to meet these goals. For example, switching to more electric vehicles, reducing noise and improving safety. These initiatives need to be accomplished alongside major changes in transport and logistics resulting from the Covid 19 pandemic. The effects of Covid 19 and changes in consumer patterns towards more online shopping and home delivery has led to additional challenges for urban logistics (DHL, 2022).

To plan for urban logistics means to plan the transport of goods, equipment and waste to, from, in and through urban areas (Taniguchi et al., 2001). The public planning at national, regional and local level is regulated through laws that span from the strategic to the implementation of a project or renovation of a building. On the strategic level the main consideration is the urban structure and how to integrate land use and transport for sustainable development (Næss, 2006; Banister, 2008). On lower levels of planning, considering the specific land use and the consequences for transport will be more important (Allen et al., 2014). As part of the planning, the modelling of the general impact of urban logistics on the urban structure or the consequences from measures like vehicle routing, ITS measures, deliveries, e-commerce, consolidation centres and the like plays a central role of the planning process. At the strategic level the modelling needs data at the city level but at the lower levels of planning the input to the models needs to be more detailed and operational. However, the modelling of urban logistics has been characterised by the lack of data and the poor quality and new technologies offers the possibility to include data from new sources if it achieves good data quality. The solution to improve the situation is to include private stakeholders into public planning resulting in collaborative urban freight planning (Lindholm, 2013; Bjørgen et al., 2019, 2021).

Digitalisation and technological innovations allow consumers to shop, travel, dine, and access entertainment and, using technology, consumers want these services delivered straight to their home promoting the on-demand-economy. Following this, freight volumes are expected to grow by 40% by 2050 (McKinsey, 2017). This development is incompatible with the environmental targets and liveability interests of the public sector achieving essentially CO_2-free urban logistics in major urban centres by 2030 (Clark, 2016; European Commission, 2016). Municipalities at the local level need methods of governance to address these competing interests, thus incorporate emission cuts while at the same time find ways to plan and manage the potential increase number of freight deliveries. The methods and modelling of urban logistics can in this instance take advantage of new forms of data in addition to the data that the local level government already collect.

Big Data refers to structured and unstructured data generated automatically as a part of transactional, operational, planning and social activities, or the linkage of such data to purposefully designed data (Thakuriah et al., 2017), like data from different types of sensors. Sensors are devices that responds to a physical stimulus (such as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control) (Merriam-Webster, 2022) Many vehicles have integrated sensors, but sensors can be attached to a vehicle or be stationary. For instance, CCTV or other cameras can be defined as a sensor often matched with machine learning that translate the images into data (OECD, 2019). The use of big data including those that come from sensors gives rise to technological and methodological challenges but has potential for improving both operational aspects and planning for urban logistics (Choudhury and Box, 2021). Smart technology is closely linked to data mining applications, focusing on knowledge discovery based on big data of emerging mobility patterns (Thakuriah et al., 2017).

The article combines knowledge on practitioners needs for data gathering through sensors with the current situation for integrated land use and transport planning of urban freight and freight partnerships in the context of network governance (see for example, Sørensen and Torfing, 2009) with private and public stakeholders. The research question is: *What could be the role of sensors in planning for sustainable digital urban logistics?* The research question is divided into three sub-questions:

1) What is the role of different levels of government in using sensors for urban logistics purposes?
2) What is the potential of sensors importance in planning for urban logistics at the local level?
3) How can experiences from current freight partnerships help frame sharing of urban logistics data?

The article is structured according to material and methods, results and discussion. The next section provides an overview of

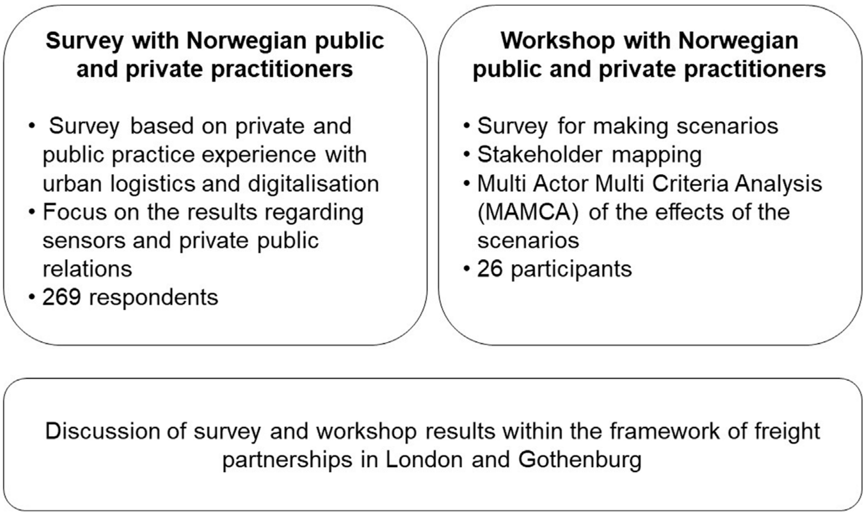

FIGURE 1
The overall framework for the data collection.

the survey and workshop methods used for data collection and the data resulting from the data collection. After an overview of the findings from the research, the article presents current discussions in literature and how sensors can be categorised. The discussion considers the impact sensors can have in the formal planning processes, the central role of local government in applying sensor for urban logistics purposes and experiences from freight partnerships in London and Gothenburg, before the study is concluded with implications for future planning.

2 Materials and methods

2.1 The overall framework for the data collection

The material for the article has two main sources, as shown in Figure 1. The survey and workshop provide the practitioners view while freight partnerships in London and Gothenburg provide the framing of the discussion on digitalisation and use of sensors relevant or urban logistics.

2.2 Survey

The survey was carried out among Norwegian practitioners working with urban logistics. Before the survey a review of the state-of-the-art literature helped define the categories of variables for digital solutions useable for urban logistics. The categories of variables were defined to be 1) freight platforms, 2) smart warehouses, 3) smart inventory, 4) personalization of services, 5) online shopping, 6) omni-channel, 7) smart homes, 8) sharing economy, 9) drone deliveries, 10) smart containerization and 11) dematerialization of transport. The questions were created with the aim to get the respondents to consider these 11 digital solutions in relation to 1) CO_2, land use, 2) ease of access, 3) air quality, 4) number of vehicles, 5) vehicles kilometres and 6) cost. In addition, the survey contained questions about expectations for public policies, plans and services and about changes necessary due to Covid 19. Due to the scope of this article not all the survey questions are presented but rather the attention is on questions related to sensors as well as the consequences of digitalisation for public policies, plans and services.

The survey targeted both private and public actors including freight deliverers, distributors, public administrations that works with freight and private Non-Governmental Organisations. The survey was sent to the researchers' Norwegian contacts and relied on snowballing, that meant relying on the contacts forwarding the e-mail with the link to the survey. The total number of respondents were 269 with 127 from private sector, 29 from the public sector and three from Non-Governmental Organisations. In addition, 110 respondents did not want to give an answer to which sector they represented. The actors from the survey are therefore not divided according to role.

2.3 Workshop

After the survey a workshop discussed the finding with a primary objective to study how digitalisation of freight transport

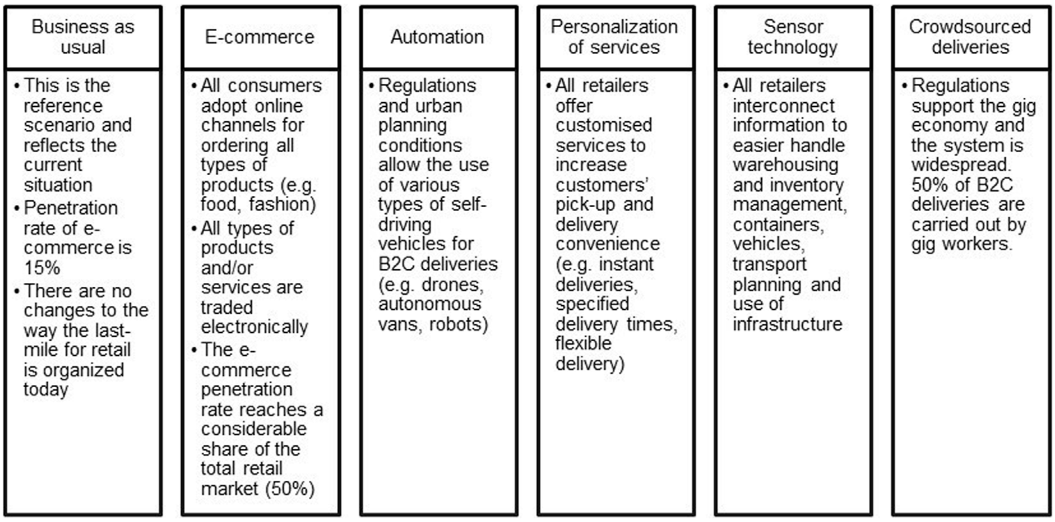

FIGURE 2
The MAMCA scenarios (Verlinde, 2020).

challenges governance, policy, organisation and decision-making in the public sector further. To that end, Norwegian public sector representatives at different levels, shippers, receivers, logistics service providers and Non-Governmental Organisations met at a workshop to discuss and validate draft findings and to assess how participants think digitalisation will change and affect urban logistics (Verlinde, 2020). The workshop was facilitated using the Multi Actor Multi Criteria Analysis (MAMCA) methodology (Macharis et al., 2019) to structure the discussion.

The MAMCA methodology and modelling tool has been developed as an extension of traditional multi-criteria decision analysis which explicitly accounts for the objectives of the stakeholders involved in a certain decision-making process (Macharis, 2005; Macharis, 2007; Macharis et al., 2019). This means that a set of scenarios (Figure 2) had to be created before the workshop. Based on the first survey a second survey were sent to those invited to the workshop. In total, 39 practitioners completed the survey even if not all of them took part of the workshop. The researchers arranging the workshop selected the five best-known trends as alternatives. Figure 2 lists the alternatives and shows how they were presented to the participants. The workshop took place on 27 May 2020 with 26 participants and a team of four researchers documenting the workshop. The workshop was organised online because of the COVID19-crisis and consequently the timeline had to be reduced to 2 h due to the online format.

During the workshop, the MAMCA methodology was used to identify the challenges and opportunities for stakeholders in urban logistics which are the result of a technology that is integrated or applied in urban freight transport. A second output is a ranking per stakeholder allowing to identify the most important stakeholders in the decision-making process along with their criteria. The material gathered in the workshop was fed into the MAMCA modelling tool to produce charts showing the effects of the scenarios.

3 Results

3.1 Results from the survey with practitioners

One of the aims of the survey is to map the practitioners own understanding of which digital transformations are the most prominent in urban logistics. In addition, the survey addresses the degree of implementation and maturity for implementation of the various forms of digitization to be able to say something about which digital transformations the players in the market themselves consider to be the ones with the greatest potential. Digital solutions already in use compared to the use of the same digital solutions for the future (next 5 years). Figure 3 shows how the participants consider the impact of the current and future impact for sensors. Compared to the current use of digital solutions in the survey, the participants consider future impact will be higher.

The survey asked the participants to compare the current situation for specific digital solutions that may influence the different themes in urban transport. Unlike for the other technological solutions in the survey, the participants perceived sensors as important for urban logistics as whole

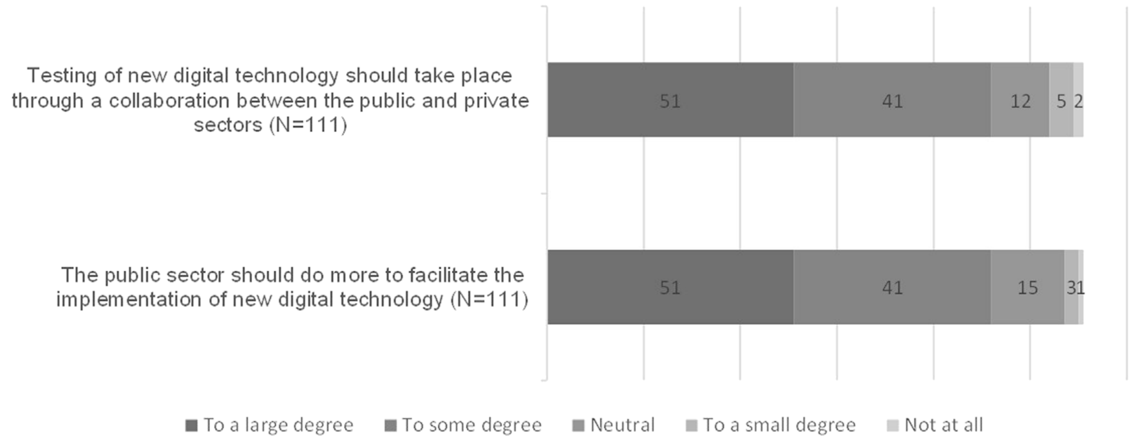

FIGURE 3
Answers regarding sensors to the statements "To what degree would you say that the following trends has had impact on urban transport until now" and "To what degree would you say that the following trends will have impact on urban transport in the next 5 years." Source: survey.

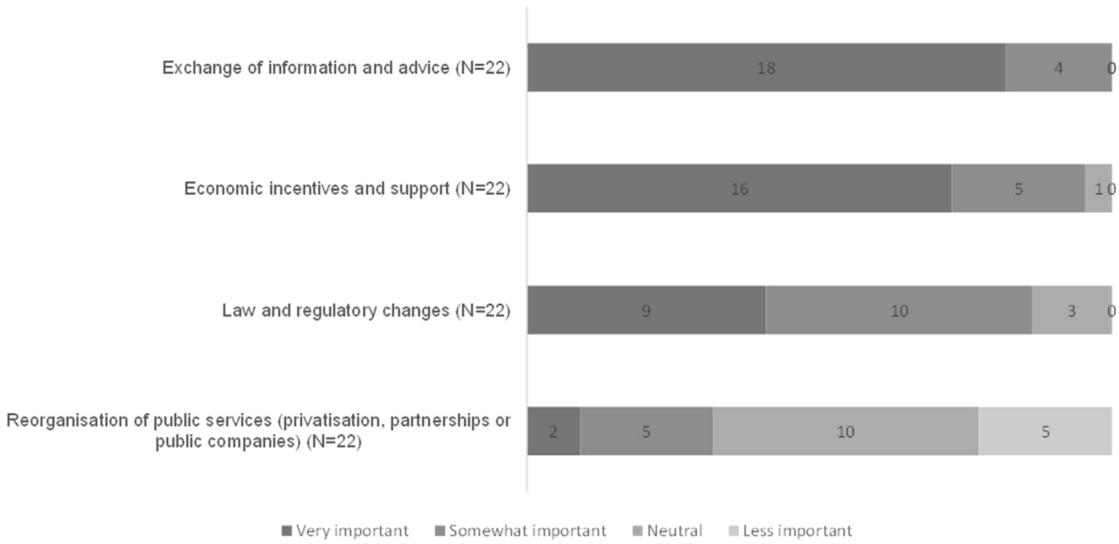

FIGURE 4
Statements concerning role of public sector. Source: survey.

including reduced CO_2, more efficient land use, better ease of access for vehicles, better air quality, reduced number of vehicles in the transport system, reduced number of vehicles kilometres and reduced costs.

To assess the role of the public sector the survey addressed several questions about expectations the different actors have regarding public sector facilitation and cooperation. In the survey 84% of the respondents expect the public sector to act as facilitator for the possibilities and challenges urban transport and digital transformation create. A little less than 42% of the respondents expects the national-level government to have the main responsibility, 20% of the respondents expects the regional-level government to take main responsibility and 39% of the respondents expects the municipal-level government to take main responsibility. The survey also shows that 46% of the respondents largely believe, and 37% of the respondents to some extent believe, together 83% that the public sector should do more to facilitate the implementation of new digital technology (Figure 4). In addition, 83% respondents largely believe or to some extent agree that the public and private

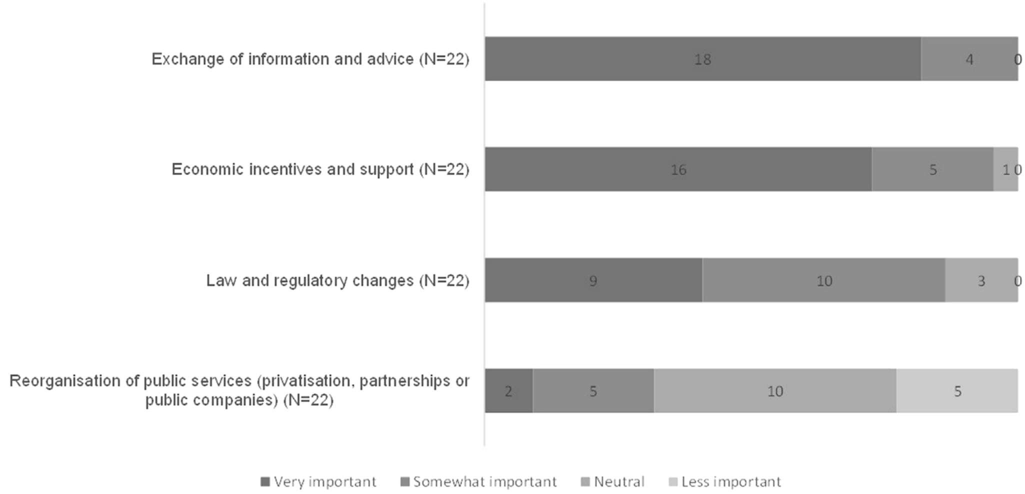

FIGURE 5
Answers to the question "Given that the businesses is experiencing challenges with COVID-19, how important do you think the following of public administration instruments are to handle the situation?". Source: survey.

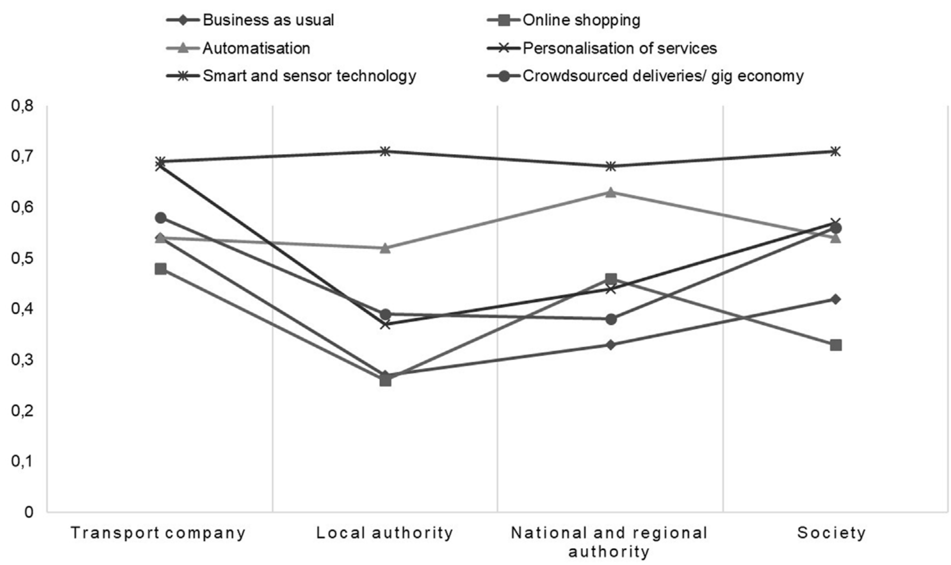

FIGURE 6
Overall modelling result from the workshop using the MAMCA modelling tool (Verlinde, 2020).

sector should collaborate for testing and implementing new digital technology.

As the survey was sent out during the Covid 19 pandemic, it included questions about the Covid 19 pandemic regarding the experiences the private businesses has had and what they consider the most important public administration instruments are to handle such a situation. Figure 5 shows that businesses expect the government to contribute most importantly with exchange of information followed by economic incentives and support from the government to those businesses experiencing challenges. However, the businesses responding rate law and regulatory changes and reorganisation of public services as less important but not unimportant.

3.2 Results from the workshop using the MAMCA method

In the workshop the effect for different stakeholders representing private transport companies and local, regional and national level government agencies, assessed five different scenarios according to the stakeholders view as well as for society as a whole and not only their own interests (Verlinde, 2020). The sensor scenario suggested a future where all retailers interconnect information to more easily handle different parts of urban logistics on different scales like warehousing and inventory management, containers, vehicles, transport planning and use of infrastructure. All the stakeholders saw this scenario as the most important for them. As Figure 6 show all the stakeholders feel that this scenario will contribute most to their individual criteria. Overall, there seems to be a strong technology optimism in the municipalities taking part in the workshop. The representatives from the municipalities give high score to both sensors and automatization, but less so on personalisation of services, assuming that the first two scenarios are easier to regulate for local authorities than personalisation of services. However, all stakeholders prefer the sensor scenario.

The workshop also uncovered that implementation of new digital solutions is important for urban logistics. According to all the participants in the survey, all levels of government should be at the forefront with regulation of digital solutions and use the data in strategic work on how to utilise and develop good urban spaces. Unrelated to this, transport companies see challenges for digitalisation in general and fear the high investment costs and the acceptance of the digital solutions by their drivers, and this also needs to be addressed as part of the implementation of new digital solutions.

3.3 Collaborative freight partnerships in London and Gothenburg

For urban logistics freight partnerships can become an important route for both triple helix collaboration and sharing and producing urban logistics data. Freight partnerships in this context are a version of public-private partnerships defined as "A long-term partnership between freight stakeholders concerned with urban freight, that on a formal or informal basis meet regularly to discuss (and sometimes find solutions to) problems and issues that occur in the urban area" (Lindholm and Browne, 2014, p. 3). A freight partnership is also an example of network governance between private and public stakeholders in practice. There are several examples of freight partnerships (Allen et al., 2010; Lindholm and Browne, 2014; Quak et al., 2016), but two relevant examples are the Central London Freight Quality Partnership in the United Kingdom and Göteborg Godsnätverket in the city of Gothenburg in Sweden. Both freight partnerships were formed in similar ways when it comes to type and number of stakeholders, number of meetings and topics discussed (Quak et al., 2016).

In London, the Central London Freight Quality Partnership was established in partnership with Transport for London in 2006 (Central London Freight Quality Partnership, 2022a). The partnership consists of public sector organisations as Greater London Authority and the Metropolitan Police and the central London boroughs of Camden, City of London, City of Westminster, Islington, Kensington and Chelsea, Lambeth and Southwark. Private sector organisations trade associations and professional institutes and freight researchers are also represented as well as local businesses and employers. The partnership is based in the Transport Studies group at the University of Westminster. Membership of Central London Freight Quality Partnership is open to individuals and organisations that have an interest in improving freight movement and servicing activity in central London.

The partnership in London aims at creating a common ground to develop an understanding of freight and logistics issues in central London (Central London Freight Quality Partnership, 2022a). They aim at developing sustainable solutions for freight and services, share good practice and to discuss and respond to proposed initiatives affecting freight and logistics. For instance, the partnership, the partnership gets information from the boroughs on the planning situation and in some instances the partnership visits future sites where there are planning initiatives to get better understanding of a planning initiative. The partnership responds to several planning initiatives with a joint statement to the planning authorities. The partnership also commissions reports and contribute to research on freight. In addition, the partnership provides networking opportunities for all the partners. The partnership has a web sites where they share information and announce events and meetings.

One example from a case presented to the Central London Freight Quality Partnership at a meeting sharing results with stakeholders (Central London Freight Quality Partnership, 2022b; Talberg and Overton, 2022). The presentations explain how a sensor provider partnered with the John Lewis Partnership to map and consequently reduce pollution impact on the environment and the neighbourhood of a John Lewis retail facility. Sensors and data handling platforms enabled John Lewis to identify, manage and reduce transport and site-based emissions. The 6 months test identified the most polluting vehicle types and proved noise pollution compliance proven but also specific site pollution and identified problems. The

TABLE 1 Different types of sensors with different characteristics and ownership.

Type of sensors	Characteristics	Typical sensors	Data gathering	Data storage and sharing
Integrated sensors	Sensors that is part of a device or a vehicle like a smart phone or a truck. Some integrated sensors have inbuilt (edge) computing	GPS Geofencing Operational sensors Radar	Passive (active if app or similar is installed)	The provider of the device will usually store the data. Apps might use the data for different purposes like journey planning. Some of the data might be available for the owner of the device
Sensors in the urban realm owned by public services	A sensor placed in the urban realm, for instance counting traffic or measuring air pollution	CCTV Inductive loop Piezoelectric film, cable or element	Passive	The owner will store the data. Some public services shares data in GIS or other platforms
Sensors on private property in private ownership	A sensor placed on a building or private property	Low cost sensors	Active	The provider will store the data and the owner will have access to (processed) data. Can be shared with stakeholders and public services
Free floating sensors	A sensor placed on a vehicle or a person with intent to collect data	Low cost sensors Fitness sensors	Active	The provider will store the data and the owner will have access to (processed) data. Can be shared with stakeholders and public services

test resulted in scientific evidence and presented insight that was shared with the partnership in London.

In Gothenburg, Göteborg Godsnätverket was established in 2005 through an EU research project (Svensson, 2007; Browne, 2021). The partnership has no specific funding but are run by the local traffic authority in the municipality (Lindholm and Browne, 2014). From the start the partnership had eight participants. As in London the partnership consists of public and private sector organisations including the municipality of Gothenburg, transport operator and trade associations. In 2007 with a new chair, the partnership was expanded to 15 participants including property owners and vehicle industry as participants (Browne, 2021). Even more changes happened in 2012 with a new chair including more participants involving more city authorities, road administration. In 2016 political participation was added to the partnership. In 2020 number of people working on freight increased and the chair also changed.

The aim of the partnership in Gothenburg is to involve the partners in the changes in urban logistics and increase the knowledge of municipal activities. The partnership should discuss cost effective distribution in the inner city, finding solutions to logistics and exchange knowledge and best practice solutions (Jäderberg, 2012). Quak et al. (2016) fond that the main outcome of the partnership in Gothenburg has been a better exchange of information between participants and an increased understanding of each other's problems. In addition, the partnership has had concrete effects including a higher level of successful enforcement of regulations within the urban area, increased number of "walking speed areas" and a length limitation for vehicles in the inner city, and a parking for heavy vehicles brochure explaining restrictions. Unlike the Central London Freight Quality Partnership, partnership in Gothenburg does not have its own webpage where minutes or research are shared, but there is some information on the webpage of the transport office in Gothenburg municipality. However, minutes are sent to the participants of the partnership meetings.

Both freight partnerships have addressed the need for freight and urban logistics stakeholders to meet, discuss and give input to the freight part of urban development (Browne, 2021). Even if the organisation and running of the partnerships are somewhat different, they have become established as partnerships over time. The freight partnerships have in common that the examples of shared information within the freight partnerships have related mainly to information on future transport changes, changing the access arrangements for streets as result of decisions to increase space for walking and cycling and sharing information on deliveries from changes in transport and logistics resulting from the COVID-19 pandemic.

Quak et al. (2016) also discuss the weaknesses of freight partnerships and define these as lack of outputs, a meeting structure that allow inactive participants to attend without sharing information, lack of participation of stakeholders from certain industry sectors, the partnership is, and there is a lack of funding to hold meetings or attend meetings. To get more results from partnerships Quack et al. (2016) has suggested that the framework of a Living Lab concept could result in a more action driven network to counteract some of the current weaknesses. For the Living Lab concept to be useful for urban logistics it has to connect of all relevant stakeholders and business models within a city, with a joint recognition of a problem and solution spaces, it has to have the means to collectively make predictions of the effects, based on simulations, gaming or more simplified means of analysis and the Living lab has to measuring of impacts and agreements to be able to respond to this with the aim to ultimately deploy a solution.

4 Discussion

4.1 Growth in types of sensors and sensor data in urban logistics

The growth and development of sensors offers new opportunities to support the urban logistics challenges. There are different types of sensors with different characteristics and ownership depending on if they are integrated sensors, sensors in the urban realm owned by public services, sensors placed om private property in private ownership or free floating sensors placed on a vehicle, see Table 1. The sensor provider gathers the data that will be stored and might be shared in a platform either as raw data or analysed data. Some of these are open access and some are by design compliant to EU's general data protection regulation (GDPR) which makes them easier to share. Data gathered as citizen science, defined as data collected by non-scientists (Haklay et al., 2021) or crowdsourced data (Sternberg and Lantz, 2018) can be shared with municipalities or other government agencies and stakeholder groups under certain conditions. Data-enabled services and solutions have the potential to address many of the freight sector challenges (Choudhury and Box, 2021). For urban logistics, sensors can give input to processes such as interconnecting information for warehouse and warehouse management, containers, vehicles, transport planning and infrastructure. For instance, GPS data has been used for mapping trucks and cabotage in the Scandinavian countries (Sternberg et al., 2015) or the use of small electric vehicles in Norwegian city centres (Jensen et al., 2022).

The sensor technology is advanced to a stage where it is no longer described as a new, innovative (DHL, 2022). It has been argued, especially by the industry, that sensors will enable the development of evidence-based freight investment decisions and policies that align with industry priorities and improve the way freight infrastructure investments are being assessed (Choudhury and Box, 2021). In practice, however, there are several challenges that must be overcome due to the complexity of the freight and logistics sector and the diversity of the stakeholders in the industry. There are legal and institutional barriers as well as processes, standards, and technical issues that must be resolved. In addition, the many and different stakeholder and cultures can be barriers to data collection and data sharing as well as additional costs and commercial considerations that comes with using sensors. Still there are some examples of using sensor data in several ways like software as a service, crowdsourced apps, sharing portals and data stores, but these applications or storage solutions would benefit if more data were available for sharing, if the benefits for the data providers was more explored and Public Private Partnerships for data and statistics renewed (OECD, 2019; Choudhury and Box, 2021). The emergence of big data and the private sector's ability to process it has created renewed attention regarding public-private data partnerships. Such collaboration can provide governments with new and granular data in a timely and cost-effective manner. Another advantage of Public Private Partnerships according to OECD (2021) is that a municipality at local level can tap into the competences, skills and technologies of partners to perform advanced analysis from holistic sources of data and *vice versa* for the private partners.

Already many supply chain organizations have put data analytics at the top of their strategic priorities, yet many still struggle to systematically and effectively make use of sensor data. One important part of effectively using sensor data is to share the data (OECD, 2021). However, there are several barriers for data sharing of data from sensors and other new sources (Allen et al., 2014). The barriers include questions about legality but also the need to supplement data with other data sources as these new technologies do not necessarily provide all the data that would have been collected in a traditional survey. In addition, and the co-operation and agreement needed between the public and private sector to share the data could be a challenge that needs to be solved.

There are several examples of open data policies where data and application programming interfaces are made available for private innovation purposes across different sectors. Data collected by sensors are often more detailed and diverse than the owner needs or they recognise that others can be interested or make use of the data collected. This have resulted in open data policies. For instance, Transport for London states that their open data have economic benefit in that the open data could lead to innovation for other actors, especially small innovation enterprises (Deloitte, 2017). Deloitte (2017) suggest that economic benefit comes from open data since they can facilitate the development of technology enterprises generating employment and income. Likewise, open data can contribute to innovation by using the data in the designing and building applications, services and tools with Transport for London's data and application programming interfaces. Norwegian examples show the same rationale for sharing data for instance weather data and application programming interfaces based on collecting weather data from private weather stations in Norwegian homes (Yr, 2022). Public agencies like the Norwegian Public Roads Administration share traffic data from sensors with the public through a web portal (Norwegian Public Roads Administration, 2022).

TABLE 2 How to include sensor data into planning practice across government levels.

	Local level	Regional level	National level
Today	- Responsible for planning after the planning and building act	- Responsible for public transport and public transport planning	- Planning guidance
	-Planning guidance to local actors	- Responsible for regional roads	- expectations to planning on local and regional levels
	- Strategic plans and strategies that frame local planning (formal process that includes participation)	- Planning guidance to local level	- Can have formal objections to planning
	- Contact with local actors	- Strategic plans and strategies that frame local planning (formal process)	- Solve formal objections to local plans
	- Provide data sets for modelling	- Can have formal objections to planning	- Clarify public-private responsibilities in planning
	- Adopts procurement rules	- Provide data sets for modelling	- Provide a national transport plan (formal process)
	- Host Living labs and other collaborative initiatives	- Adopts procurement rules	- Provide data sets for modelling - Testing and funding of pilots
			- Adopts procurement rules
Future inclusion of sensors	- Include freight and urban logistics in strategic plans and strategies	- Include freight and urban logistics in strategic plans and strategies	- Provide solution for sharing of data e.g., sharing platform framework and guidelines
	- Specific strategy for sensor data	- Adopt policy for sharing traffic data from sensors owned by regional authorities including public transport data	- Develop and implement sharing strategy guidelines for other actors
	- Adopt data sharing strategy	- Adopt innovative procurement rules	- Provide neutral and available storage of data over time
	- Adopt innovative procurement rules	- Include reporting of data in public procurement processes like public transport tendering	- Provide procurement rules
	- Include reporting of data in public procurement processes	- Alternative host to freight partnerships	- Adopt innovative procurement rules
	- Host freight partnerships	- Instigate, take part in and fund pilots	- Include reporting of data in public procurement processes
	- Instigate, take part and fund pilots		- Instigate, take part in and fund pilots

One early example of a state level government policy is the Dutch data sharing policy (Ministry of Economic Affairs and Climate Policy, 2019). The policy highlights that it is important for businesses to be able to share data with other businesses. For data sharing to take place responsibly, the policy states that the data sharing must happen with respect for the rights and legitimate interests of all concerned, such as privacy, autonomy and commercial confidentiality. The role of the state level government in the policy is to encourage the sharing and re-use of data and limiting risk in areas such as privacy and cybersecurity. The Dutch suggest using a new type of agreements where the state level government play a facilitating role in keeping with the principles in the policy. According to the Dutch state level government such agreements have been created to make controlled, simple and uniform agreements about data access but with the businesses retaining control of and access to the data concerned. The Dutch policy encourage data-sharing coalitions, in which existing and new data-sharing initiatives can inform and inspire one another. The policy does not have all the answers regarding data sharing and possible pit falls and will therefore commission research into the facts and risks relevant to owners or long-term users regarding access to data from pieces of equipment that produce data when they are used. Also, the policy does not deal with data sharing between businesses and government (B2G data sharing).

Urban logistics is already characterised by the involvement of multiple private and public stakeholders, since the operations takes place in a city intersecting with other activities (Cré et al., 2016). Many solutions for improved performance lie in the interface between these stakeholder groups (Irvin and Stansbury, 2004). Urban freight is a private matter, but still, the public sector has a strong interest in its execution, due to the negative externalities as well as the impact on urban life. There are several examples of freight partnerships in European cities (Lindholm and Browne, 2013; Lindholm and Browne, 2014; Browne et al., 2019). These triple helix partnerships bring together public actors such as city authorities with private companies such as transport companies and the receivers of

TABLE 3 Use of sensors in municipal planning.

Type of sensors	Data collection	Estimating prediction capacity	Access to data from sensors	Influence on local urban logistics planning processes
Integrated sensors part of a device or a vehicle	Passive collection of data	Time series analysis	Access restricted by owner, possible municipal access through agreements or procurement	Travel data for modelling and route planning
	Collects data during the device's lifetime	Evaluation of device capability		Input to strategic planning or zoning
Sensors in the urban realm owned by public services	Passive collection of data	Comparison with traditional (traffic) counting methods to align use of sensors and results from sensors	Municipal access through ownership or agreement with other levels of government	Traffic data for modelling
	Collects data during the sensor's lifetime	Time series analysis		Input to strategic land use planning or zoning
Sensors on private property in private ownership	Active collection of data	Machine learning adjustment of sensor	Municipal access through agreements	Knowledge on local phenomena and citizens initiatives
	Usually collects data for limited time and in connection with a project or pilot	Time series analysis for results		Input to zoning or planning permissions
Free floating sensors placed on a vehicle or a person	Active collection of data	Machine learning adjustment of sensor	Municipal access through agreements or procurement	Knowledge on local phenomena, citizens or corporate initiatives
	Usually collects data for limited time and in connection with a project or pilot	Time series analysis for results		Input to zoning or planning permissions

goods (e.g., shops, construction sites, offices etc.). The working arrangements of such partnerships vary considerably, but essentially, they share the same goal which is to create a better understanding of urban logistics in order to reduce the impacts and support measures that can lead to greater efficiency.

4.2 The potential of sensors in planning for urban logistics

The results from the survey and workshop indicate that sensors are already important for urban logistics and will be even more important in the future. This means that different types of sensors can provide data for urban logistics planning according to the what kind of data is collected and how they are used and shared. Especially consultancy reports point to how sensors can be used and provide examples of how they have been used so far (see for example, Choudhury and Box, 2021). The examples show the potential benefits of low-cost sensors (DHL, 2022) while recognising that there are some challenges with these kinds of new or big data compared to more traditional data gathering methods. This is also discussed in the literature as a challenge when it comes to new and big data (Allen et al., 2014).

The survey showed that the practitioners expect that the public sector at local, regional or local level in Norway, should do more to facilitate the implementation of new digital technology. In addition, most of the respondents largely believes or to some extent agree that the public sector must take responsibility for testing and implementing new digital technology, including sensors. This means that public sector has an important role to play when it comes to new knowledge needs and how these needs can be enhanced with knowledge from sensors or other digital tools and data.

Table 2 shows how sensors can be included within planning practice at different levels for a holistic approach to sensors for the public sector. It is important to include the use of sensors and of the data output from the sensors in strategic planning, data storing and sharing, procurement and testing of pilots for a holistic approach. Sensors could be an important source of information and particularly provide data sets for modelling of urban logistics which has been hard to cover by using traditional sources of transport data (Ballantyne et al., 2013; Allen et al., 2014). However, using sensor data challenge current practices of both collecting and sharing data. Hosting a data sharing platform could be possible at local level since municipalities are responsible for planning data. The national level is another possible solution as the Norwegian Mapping Authority Statistics Norway and the Norwegian Public Roads administration all store and share some central national datasets as open data. Regardless of the level given the responsibility of hosting sharing platforms, the state level should provide the framework and guidelines for sharing platforms to ensure a holistic solution. This becomes especially important when sharing platforms include data from private sensors from formal and informal projects to ensure data quality. It will also be an important question to consider where the responsibility of the government ends and data cleaning, storing and sharing become a private or corporate issue.

4.3 The central role of the local level in applying sensors in urban logistics planning

The municipalities at the local level are considered by the survey participants to have a more central role than the other levels of government in acting as the facilitator for the possibilities and challenges urban transport and digital transformation create. So far, the knowledgebase has been considered as weak for modelling of freight and urban logistics data is scarce resulting in too little attention being given to urban logistics in city planning (Ballantyne et al., 2013; Fossheim and Andersen, 2017; Bjørgen et al., 2019). Table 3 shows how data from the different types of sensors can be accessed and how they can influence urban logistics processes at the local level. The input can be on three levels, either strategic planning, zoning or planning permission level. The strategic planning needs data relevant for the regional or local level while zoning or planning permission levels need data relevant for a plot or project. The latter two data sources need to be more detailed than for the strategic level. All three levels need data for modelling of urban logistics and data that are compatible with other data sources that provides the knowledgebase for the modelling of urban logistics.

The potential for sensors and sensor data needs to be assessed to estimate the prediction capacity of the sensors and the output from the sensors. There are several methods to do this, from comparing the results from sensors over time or comparing the capability with other data sources to find out if this is the right sensor or data collection method. Some sensors correct themselves through machine learning to give more correct output over time. As the sensor data are collected in a different manner and have different properties, the use of the data needs to reflect what the sensor can do, and the collection of data needs to take account of that. Sometimes other sources are needed to support data from sensors in order to deliver the input to plans and the modelling that is needed. In addition to the need to supplement this data with other data, Allen et al. (2014) points to legality issues and the co-operation and agreement needed between the public and private sector to share data, noting that there is a possibility to collect significant quantities of needed urban logistics data.

There is a range of planning processes where data from sensors could play a role. On the strategic level this includes sustainable urban logistics plans or integrated land use and transport plan where logistics and freight are addressed at a regional or city level. In Norway sustainable urban logistics plans are still new, but experiences from making such plans (for example, Municipality of Bodø, 2020) reveal that especially the delivery situation in the city centre needed to be investigated. Here the investigation was done by students but in situations like this, sensors could have been used instead or in combination with interviews and fieldwork. There are several examples of sensors being tested at lower levels of planning like smart city pilots and urban lab projects where sensors have been used to measure the level of sand (for icy roads in the winter) in sand boxes, icy roads and more (for example, Municipality of Stavanger, 2022) to when a loading bay is free or taken so that deliveries become more predictable (Letnik et al., 2018) and these give an indicator for how sensors can be applied in the future and how big data can be presented to the users. Already some Norwegian municipalities like Oslo convey results on websites either informal (Municipality of Oslo, 2022a, www.klimaoslo.no) or part of the formal reporting (Municipality of Oslo, 2022b, https://statistikkbanken.oslo.kommune.no/webview/), even if the data here is still mostly collected by more traditional methods and not necessarily relevant for urban logistics at present. This situation will change as urban logistic gets a higher priority (Bjørgen et al., 2019) and when freight and deliveries become more visible as cities restrict private car access and reduces parking space for private cars in the city centres. More and better data on urban logistics will also improve the conditions for modelling freight as the input to the modelling will be better with more knowledge and data available.

In addition to the three planning levels, the operations and regulations level will be interdependent as they influence each other. A strategy can lead to a shift in practice or *vice versa*. A guide for logistics planning in Sweden (Region Skåne, 2017) highlights the relationship between the levels and the need for establishing ways of working which acknowledge the interdependency. For instance, the operations and regulations are especially important for the private actors and therefore need to be connected to and aligned with the strategic level. In addition, some of the data collected with sensors can be important for both before and after assessments of pilots and new regulations that in turn might influence the other planning levels. To be able to use sensors more consistently, the local level must both start

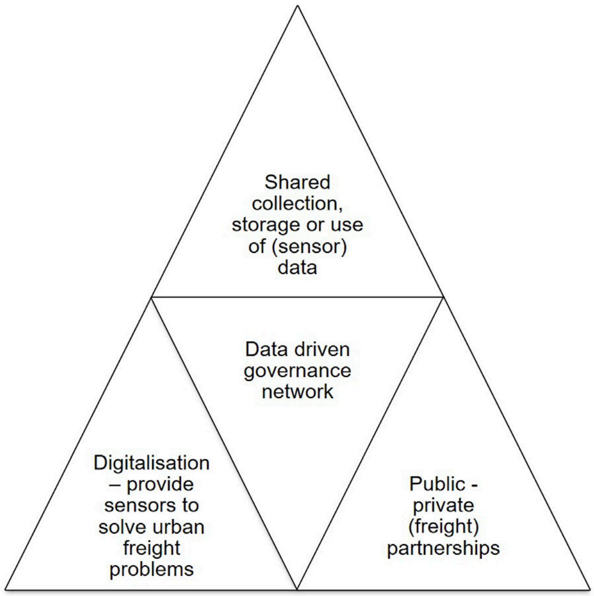

FIGURE 7
Elements in data driven governance network.

applying sensors actively in their data collection as well as renew procurement policies. The procurement process should secure that data is collected as part of the service or product that is procured, for instance when it comes to delivery of goods or collection of waste, and that the local level gets access to the data collected actively or passively as part of the process.

The use of indicators can be either passive or active, and this is influenced both by the type of sensors and why the data is collected. Integrated sensors and sensors in the urban realm most often collect data independent of the planning situation as they are permanent and therefore passive sensors. For instance, traffic data are collected continuously and provide data to several types of planning processes from strategies to testing of pilots. The data are usually collected in the same place, or under the same conditions, for longer periods of time, and can therefore produce long time series of data showing how traffic develops over time. Sensors on private property or free-floating sensors, especially those used for citizen science can have a shorter lifespan and typically collect data for shorter periods, to show the current situation for a local problem that the citizen wants to influence or showcase and are therefore characterised by a more active use for a limited time period. The active and easy to move sensors can be placed where something is about to changed, for instance, when city centres are made car free to investigate the amount for traffic present in the city centre. The active sensor can also be used an in combination with passive sensors if the passive sensors are too far apart or need to be supplemented in certain situations.

4.4 How experiences from current freight partnerships can help frame sharing of urban logistics data

The public sector's role is instrumental for change according to the practitioners taking part in the survey, but at the same time the respondents see that public and private sector must take joint responsibility for testing and implementing new digital technology. For sensors this includes both the testing of sensors, applying sensors and sharing of sensor data as discussed in earlier. In addition, during Covid 19, the private sector expected the public sector to contribute with exchange of information, economic incentives and support from the government to those businesses experiencing challenges. At the same time the effects of freight partnerships have been documented. Freight partnerships are an example of network governance with public and private stakeholders. So far examples of shared information within the freight partnerships have related mainly to information on future transport changes, changing the access arrangements for streets as result of decisions to increase space for walking and cycling and sharing information on deliveries from changes in transport and logistics resulting from the COVID-19 pandemic.

A survey from Lindholm and Browne (2014) among partnerships found that all partnerships highlight that the network and the cooperation between the participating public and private actors that the partnership encourage is important. In the partnership the municipal government get input to policy making, through dialogue and information from private stakeholders. The private stakeholders get information from the government and have the possibility to ask questions regarding ongoing and coming plans and in that way being better informed and prepared for instance for forthcoming changes in legislation. The partnership has also led to physical changes being made for urban infrastructure and signage as well as guides for physical infrastructure. Lindholm and Browne (2014) find that the outputs in general bring real benefit to all stakeholders involved in the discussion.

Even if sharing of data has not been a primary focus of the freight partnerships until now, it could become part of a more data driven governance network. The example of presenting a sensor study (Section 3.3) in the freight network in London is one way of sharing results and ways of using sensors in urban logistics projects. The project was carried out by a retailer and a sensor provider to look at the consequences of noise at a retail facility in London. One way of taking the collaboration further is to share the data themselves and not only the results from the study, both from this study and other studies carried out by the members of the partnership over time to build a database. A shared database could be useful for the members and enable changes and developments over time to be considered.

When more data like the data from London as well as big data become more available, the freight partnerships could be one channel of sharing data between partners or the wider public. With big data and data from sensors, data has become a policy issue in several countries and cities sees the sharing of data among stakeholder as instrumental and that big data leads to more shareholders collecting and requests data. It also fits with the idea of applying the Living Lab concept to freight networks suggested by Quak et al. (2016) to increase the output of the freight networks but does not depend on it. Based on the findings, Figure 7 shows how combing digitalisation (providing new sensors), shared data and public- private (freight) partnerships create a data driven governance network for urban logistics.

Sharing of data has become a policy issue in several countries and cities that, like the practitioners in the survey, see the sharing of data among stakeholder as instrumental and that big data leads to more shareholders collecting and requesting data. In the Netherlands a Dutch data sharing policy (Ministry of Economic Affairs and Climate Policy, 2019) has been implemented and stresses the importance for public sharing of data but also the importance for businesses to be able to share data with other businesses. However, data sharing must take place responsibly, with respect for the rights and legitimate interests of all concerned, such as privacy, autonomy and commercial confidentiality. The role of the Dutch national level government is set to encourage the sharing and re-use of data and limiting risk in areas such as privacy and cybersecurity. The role the Dutch national level governments have taken can easily be transferred to other countries and be an important when discussion the role of the public sector for data sharing, for example within a freight partnership.

Security and privacy issues needs to be addressed continuously and fulfil the EU's general data protection regulation (GDPR) through agreement, contracts and aggregating data. The freight partnership could use templates and contracts that allow the partners in the partnership to make controlled, simple and uniform agreements about data access while the partner that owns the data retain control of and access to the data concerned. Some experiences and examples relevant for urban logistics are other open data stores and how public authorities share data and application programming interfaces with private companies to encourage innovation and app development while retaining privacy issues by aggregating or anonymising data.

One question that remains is if the partnerships should move from triple helix to quadruple helix network including inhabitants and citizens groups and move the partnerships into the public realm as Quak et al. (2016) suggest by applying the Living Lab concept to the freight partnerships. For data sharing this might open the door for using data from citizens' sensors or crowdsourced materials from sensors. One example of the latter is that crowdsourced data was used successfully in analysing transport crimes and cabotage based on data gathered from an app used by volunteer truck drivers (Sternberg et al., 2015; Sternberg and Lantz, 2018). In addition, the market for citizens science sensors has increased and come at a much lower price than the publicly owned sensors in the public realm (DHL, 2022). The question is if they could be useful on their own or together with other sensors for shedding light on urban logistics and if the data should be made available in data sharing solutions. This and the other questions about quality and access will be up to the freight partnerships to agree on, but it is possible that the positives outweigh the negatives and that this will take the partnerships towards a data driven network governance benefiting all the partners.

5 Conclusion

Increased digitalisation within the urban realm opens up many new opportunities to use sensor data for making better planning decisions. The article set out to discuss sensors in planning for sustainable urban logistics by asking what the increased role of sensors could include, why it would be valuable and which organisations should take the lead? Use of sensor data can influence planning practice for urban logistics towards a more knowledge-based approach framed more appropriately. We found that Norwegian practitioners rate the potential of sensors in planning for urban logistics as high and that municipalities have a special role to play to make this happen independent of sensor types, ownership and data sharing. Even if municipalities start collecting, applying and sharing sensor data all levels of government must contribute according to their role to instigate a data driven network governance. The national level will have to set the rules and with this make it possible for the local level to meet the expectations of private sector. The regional level will have to support planning processes for urban logistics planning and should have a special responsibility for modelling traffic and supporting the local level with planning for better conditions for urban logistics.

Experiences from current freight partnerships in Gothenburg and London (Allen et al., 2010; Jäderberg, 2012; Lindholm and Browne, 2013, 2014; Browne, 2021) shows the importance of stakeholder engagement as a central activity that needs to form part of the strategy to increase data sharing in city logistics. At present the freight partnerships do not have a comprehensive approach to share data from sensors and other sources that digitalisation will allow for in the future. Instead, most data sharing occurs as a result of specific projects or planning initiatives. Since partnerships build trust, it overcomes inertia within and between private sector organisations and public authorities which makes the partnership a relevant place to share data as suggested in the Dutch sharing strategy (Ministry of Economic Affairs and Climate Policy, 2019) and offer a very helpful platform or starting point for sharing data. Combining the needs defined in the survey carried out among practitioners and the experience from the freight networks reveals a potential to enable more rapid development of data sharing initiatives integrating urban logistics within the planning process from the strategic level to implementation. We suggest that the freight partnership could be sharing more data for better integration of urban logistics into planning practice and that the freight partnerships could provide an environment for data driven network governance. Sensors could be shared between public and private actors within a framework that consider data use, storing and privacy issues. For instance, if the data should be shared only within the network or also with the wider public. It should however be discussed where the responsibility of the government end and when is the data collection and sharing a private responsibility.

Sensors provide an opportunity to capture data at low cost. The cost of data acquisition has made it difficult to achieve more evidence-based planning for sustainable urban logistics. Surveys are expensive and it can be difficult to gain high levels of participation among the companies providing urban logistics services. Examples and initiatives reviewed as part of the study has demonstrated the scope to apply sensor data in the increasingly digitalised urban logistics environment.

The scale of the use of sensor data to foster change to a more sustainable urban logistics system remains limited. Based on the research we consider there is an urgent need for more research and action at three different levels 1) related to implementation and the question of how sensors can be used to provide data and the categories of data that are relevant to planning decisions in sustainable urban logistics 2) related to transferability, comparability and scaling in order to achieve wider and more cohere planning related to urban logistics 3) questions of governance and issues such as legal requirements and boundaries in terms of data ownership and use.

Providing templates and guidelines for implementation actions regarding sensors would be helpful to increase the uptake and to demonstrate effective ways to capture and use data while maintaining data security and privacy. As we argue above this type of action could be supported or led by freight partnerships. To achieve transferability and comparability needs the involvement of municipalities at the local level. If this can be done in a way that brings together a range of urban areas, then this could also lead to greater scale in the application of sensor data in planning for sustainable urban logistics. Research concerning effective stellations of municipal actors and stakeholders would be an important enabling action. Governance issues need to be addressed at municipal, regional and national levels and a review of international practice could provide inspiration for such a development.

Still, the sharing and use of sensor and big data will require that the public sector, and especially municipalities at local level take the lead, and this has implications for planning. To be able to move towards data driven network governance municipal planners needs to address 1) who should take part in a freight partnership or other collaboration 2) the type of sensors to use based on needs for data 3) EU's general data protection regulation and how this influences data collection, use and sharing 4) ownership of data 5) collection of data 6) platforms for sharing data and who should have access 7) procurement 8) resilience 9) how can best practices from other sectors be relevant for urban logistics data and 10) how to move from triple helix to quadruple helix practice for instance including citizen science data into shared data platforms. A holistic approach could benefit urban logistics planning from the strategic level to the operational level as well making urban logistics more visible in the planning processes and achieving sustainability goals like the SDG and reducing CO_2 emissions according to the Paris agreement.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

MK: Conceptualisation, Methodology, Formal analysis, Lead writer of final draft. MB: Conceptualisation, Methodology, Formal analysis, Co-writer of final draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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