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City logistics for sustainable and liveable cities

Eiichi Taniguchi

(Kyoto University)

2020 FFJ/Michelin Foundation Fellow

August 2021

City logistics for sustainable and liveable cities

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Abstract

This discussion paper tackles the complicated and important problems of city logistics or urban freight transport for sustainable and liveable cities. It focuses on the use of emerging technologies including Information and Communication Technologies (ICT), Intelligent Transport Systems (ITS), Internet of Things (IoT), big data, Artificial Intelligence (AI), autonomous vehicles, and robots as well as the public-private collaborations of stakeholders. It clarifies the innovative solutions for urban freight transport issues for sustainable and liveable cities based on the experiences of planning, modelling, and evaluating policy measures, strategies, and management of city logistics in Europe, Japan, and Australia. The paper discusses the important factors for promoting city logistics such as the integrated platform, data sharing between public and private sectors, urban consolidation centres, multi-agent simulations, use of autonomous vehicles, and public-private partnerships. It concludes that the collaborations between stakeholders are critical for successful implementation of city logistics initiatives, and modelling city logistics using the simulation and optimisation techniques based on the emerging technologies is essential to anticipate the effects of policy measures and benefits for each stakeholder to make proper decisions.

Keywords

City logistics, Emerging technologies, Public-private collaborations, Data sharing, Urban consolidation centres, Modelling.

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Contents

1. Introduction

2. Literature review

2.1. Overview

2.2. Use of emerging technologies including ICT, ITS, IoT, big data, and AI

2.3. Autonomous vehicles and robots for last mile delivery

2.4 Collaborations between stakeholders

2.5 Multi-agent simulation

3. Data sharing between public sectors and private companies in some cities in Europe, Japan and Australia

3.1. Overview

3.2. Current status, issues and benefits

3.3. Discussions

4. Recent advances of city logistics in Europe, Japan and Australia

4.1 Overview

4.2 Current status, issues and innovative solutions

4.2.1 Japan

4.2.2 France

4.2.3 The Netherlands

4.2.4 Sweden and UK

4.2.5 Australia

5. Conclusion

References

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1. Introduction

Urban freight transport is important for economic growth and sustainable environment and liveability of cities. The movements of goods and freight vehicles in urban areas have increased due to the increase of e-commerce and other economic activities. However, we face difficult problems of higher costs for urban goods delivery, nuisance including traffic congestion, crashes, Green House Gas (GHG) emissions, local emissions, noise and vibration. For tackling these difficult issues, city logistics have been proposed (Taniguchi et al., 2001) and implemented in several cities around the world. City logistics provides innovative solutions for urban freight transport issues using emerging technologies of Information and Communication Technologies (ICT), Intelligent Transport Systems (ITS), Internet of Things (IoT), big data, Artificial Intelligence (AI), autonomous vehicles, robots and others (Taniguchi et al., 2020a). As many stakeholders such as shippers, freight carriers, administrators, and residents are involved in city logistics, collaborations among these stakeholders are essential for successful implementation of city logistics policy measures.

The research subject “city logistics” itself is interdisciplinary which requires wide ranged approaches from transport and logistics engineering, informatics, economics, public policy, geography, management, and others. The discipline of city logistics is aiming at balancing the economic growth and the social wellbeing of environmental friendliness, safety, security, and energy efficiency in urban areas. City logistics has three goals (Figure 1.1): mobility, sustainability, and liveability. The objectives of city logistics encompass the reduction of logistics costs as well as the decrease of traffic congestion, greenhouse gas (GHG) emissions and other negative environmental impacts, and energy consumption, and the improvement of safety and security in community. Therefore, we need to do interdisciplinary studies for tackling the complicated urban freight transport issues.

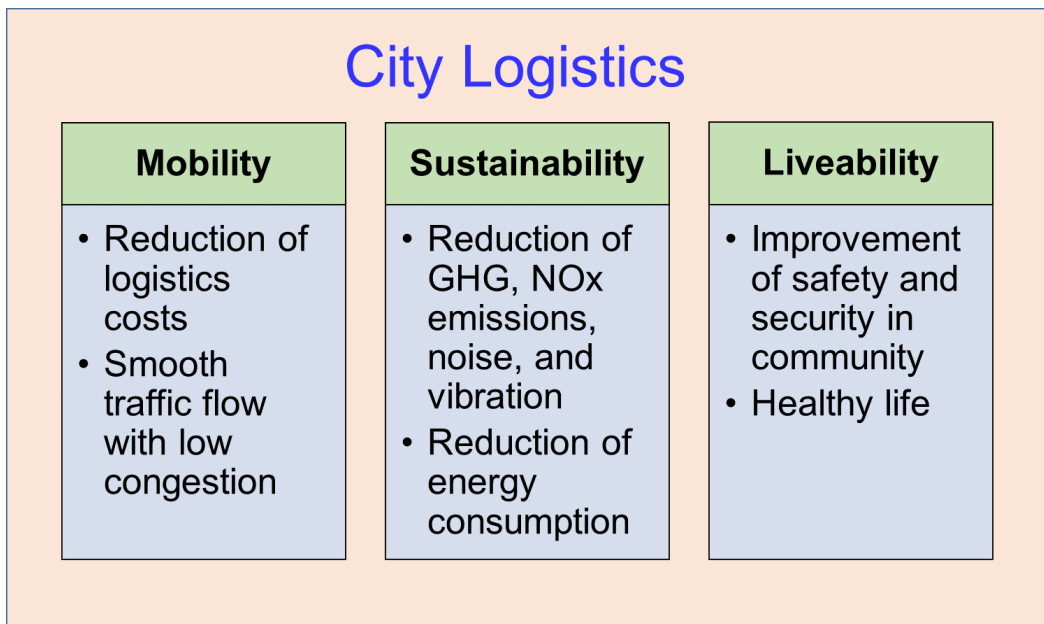


Figure 1.1 Three goals of city logistics

In the following, Section 2 presents literature reviews of important topics in city logistics. Section 3 highlights data sharing between public sectors and private companies in Europe, Japan, and Australia, discussing the issues and opportunities for sustainable city logistics. Section 4 covers recent advances of city logistics in Europe, Japan, and Australia, looking into the insights of city logistics in terms of the use of emerging technologies, policy measures, modelling, and the public-private collaborations. Section 5 gives concluding remarks.

2. Literature review

2.1 Overview

City logistics using recent innovative technologies including ITS (Intelligent Transport Systems), ICT (Information and Communication Technology), IoT (Internet of Things), big data and AI (Artificial Intelligence), autonomous vehicles, and robots is promising for evolving smart city logistics. Vehicle routing and scheduling with time windows models, multi-agent models, multi-actor multi-criteria models, and location routing models have been studied and applied in a great number of case studies for sustainable urban freight transport. Evaluating the city logistics policy measures using these mathematical models is required to understand their effects before implementing them in advance. As several stakeholders including freight carriers, shippers, administrators, and residents have different objectives, the evaluation using multiple criteria was often executed. The literature review is given below on the important topics in city logistics.

2.2 Use of emerging technologies including ICT, ITS, IoT, big data, and AI

Emerging technologies including ICT, ITS, IoT, big data, and AI are useful for establishing smart city logistics. (Taniguchi and Thompson, 2014). These technologies allow an integrated platform for managing urban freight transport systems to be provided and operated in urban areas. The function of ITS and ICT includes:

- (a) Collecting data,
- (b) Storing data, and
- (c) Analysing data for improving existing urban freight transport systems.

We can collect precise data of movements of freight vehicles and goods using ITS and ICT. For example, GPS (Global Positioning Systems) and other tele-communication technology allows us to obtain location data of freight vehicles and goods at every second. Such historical data which are stored for a long term in computers can be used for optimising routing and scheduling of delivery in urban areas. On-line data are also important for dynamic operation of freight vehicles considering traffic congestion.

Recently the IoT has become popular in production and logistics systems using sensors for measuring the location, acceleration and weight of loads of freight vehicles, the temperature within containers, as well as RFID (Radio Frequency Identification). The IoT can connect a great number of production sites, distribution centres, freight vehicles, and commodities. Networks based on ITS, ICT and IoT provide big data on urban freight transport systems.

Mehmood et al. (2017) analysed the effects of big data on city transport providing a new understanding of load sharing and optimization in a smart city context. They demonstrated how big data can be used to improve transport efficiency and lower externalities in a smart city. Bibri (2018) highlighted IoT and related big data applications for smart sustainable cities, focusing on an analytical framework for data-centric applications enabled by the IoT to advance environmental sustainability.

The important point of big data applications in city logistics is the collaborative operation of urban freight transport in sharing the capacity of vehicles, distribution centres and information systems in the sharing economy. Big data related to urban freight transport are typically owned by private companies but integration with public owned traffic and infrastructure data is needed for enhancing the operation of urban freight transport. Cleophas et al. (2019) discussed collaborative urban freight systems, identifying two key types of collaboration, vertical and horizontal. Vertical collaboration is referred to line-haul and last mile or multi-echelon distribution, whereas in horizontal collaboration partners serve the same or at least over-lapping parts of the transport network. They considered strategic, tactical, and

operational planning horizons as well as different degrees of information exchange and planning centralization.

Taniguchi et al. (2018a) presented concepts of an integrated platform for innovative city logistics with urban consolidation centres (UCC) and transshipment points (TP). The concepts encompass joint delivery systems with shared use of pickup-delivery trucks, urban consolidation centres and transshipment points based on big data analytics. These systems involve public-private partnerships among shippers, freight carriers, UCC operators, municipalities, and regional planning organisations, since the location of UCC and TP are highly related to urban land use plans and infrastructure provision as well as urban traffic management. ITS and ICT based communication systems for stakeholders are also essential for the efficient management of integrated platforms for both real-time and long-term operations. Integrated platforms can provide benefits such as improving the efficiency of urban deliveries and reducing CO₂ footprints.

2.3 Autonomous vehicles and robots for last mile delivery

Autonomous vehicles are promising technologies which can provide efficient delivery services to city dwellers. Autonomous trucks or autonomous robots have been tested for last mile delivery of goods in urban areas. These innovative technologies may improve efficiency in terms of cost savings as well as reduce the negative environmental impacts. Delivery robots are also able to provide healthy distribution system with contactless service to customers in the COVID-19 pandemic times.

Beirigo et al. (2018) studied modelling shared autonomous transportation of passengers and parcels for share-a-ride parcel locker problems in urban areas. They concluded that mixed purpose fleets for passengers and parcels performed on average 11% better than single-purpose fleets.

Boysen et al. (2018) modelled the truck-based robot delivery-scheduling problem for last mile delivery. This problem aims to find an optimal truck route and a schedule for launching autonomous robots at a stop for delivering goods to customers by minimising the weighted number of late deliveries. Simoni et al. (2020) analysed robot-assisted last-mile delivery systems and pointed out that the truck-robot systems are quite efficient if robots are employed at heavily congested areas. Last-mile delivery robots allow contactless delivery to customers which can minimise the risk of infection at the time of COVID-19 pandemic (Chen et al., 2021). Figliozzi and Jennings (2020) showed the autonomous delivery robots have the potential for significantly reducing the energy consumption and CO₂ emissions.

Scherr et al. (2019) modelled service network design for autonomous vehicles in platoons

as a mixed integer linear program. They introduced autonomous platooning in the first tier of two-tier city logistics systems. Their simulation showed that mixed autonomous fleets provide potential cost savings deployed in city logistics.

Haasa et al. (2017) studied the application of platooning in urban delivery and discussed waiting times at a transfer point and the number of platoons using microsimulation. Csiszar et al. (2018) discussed a system model for autonomous road freight transportation highlighting a structural model and an operational model focusing on system dynamics.

2.4 Collaborations between stakeholders

Collaborations between stakeholders are critical for successful implementation of city logistics initiatives. Stakeholders including shippers, freight carriers, administrators, and residents are involved in city logistics. They have different objectives and perspectives for the urban freight transport. For example, shippers and freight carriers are mainly interested in maximising their profits, while administrators try to reduce traffic congestion and global/local emissions of hazardous gases and residents are keen to ensure safety and security of communities. Therefore, they need to collaborate for planning, implementing, and evaluating city logistics policy measures.

As public entities and private companies are involved in city logistics, the Public-Private Partnerships (PPP) (Browne et al., 2014) are essential for achieving the common goals of city logistics. The first stage of PPP is identifying the problems related to urban freight transport and planning, implementing, and evaluating stages of city logistics schemes follow. In all these stages of PPP, sharing data is critical for understanding the current status, issues and finding innovative solutions. Recently ITS, ICT, and IoT allows private logistics companies to obtain precise data on movements of vehicles and goods, location of depots and demands for delivering goods. Public sectors traditionally own data on traffic congestion, crashes, emissions of CO₂, NO_x and PM (Particle Material), and infrastructure provision. Data sharing within stakeholders is beneficial for recognising the issues and planning sustainable urban freight transport in the framework of public-private partnerships. However, there are issues of confidentiality of logistics companies, costs of collecting data, regulations by law and lack of tools for analysing data.

Illemanne et al. (2020) discussed data sharing between private logistics companies and public policy makers and proposed a framework for identifying how the shared freight data can be used to satisfy the planning needs of different freight stakeholders. Moschovou et al. (2019) pointed out that the main barriers met in sharing freight data are legal barriers, resource barriers, competition barriers, and institutional barriers. Legal barriers mean the existence of laws that restrict data sharing. Resource barriers encompass the restrictions in funding and the lack of

resources. Competition barriers are derived from the confidentiality of business in private companies. Institutional barriers indicate the limitation of sharing data between various organisations.

Melo et al. (2019) performed microscopic traffic simulation for discussing the capacity sharing of the logistics parking infrastructure owned by the public authorities between private logistics companies and parents who pick up their children from school. The results showed the significant reduction in delay times, travel times, queue length, stopped times and increase in average speeds of both private transport and freight transport. Also, the fuel consumption and emissions presented the considerable reductions.

Discussing the effects of policy measures before implementing them as well as after the implementation is important among stakeholders in the PPP. Modelling city logistics helps discussions and decision making by providing the estimation of responses of shippers and freight carriers to policy measures taken by a municipality and their impacts on urban traffic and environment. Katsela and Palsson (2020) presented a multi-criteria decision model using analytic hierarchy process to support stakeholder management in city logistics.

2.5 Multi-agent simulation

Multi-agent modelling provides us with a useful tool for representing and understanding behaviour of stakeholders, i.e., shippers, freight carriers, administrators, and residents who are involved in city logistics. Collaboration between stakeholders is essential for successful operation of city logistics and a multi-agent simulation allows us to predict the effects of city logistics policy measures before implementing them in real urban areas and to find appropriate management for satisfying the objectives of stakeholders. Smart city logistics are based on advanced information systems and this aspect can be incorporated in multi-agent simulation.

Firdausiyah et al. (2019) presented multi-agent simulation models using adaptive dynamic programming which is a reinforcement learning method. In multi-agent models each agent learns to maximise the rewards which are given based on the decision of an agent. They applied these models in cases of urban goods delivery using urban consolidation centres (UCC) and concluded that adaptive dynamic programming method provided better performance than Q-learning in terms of profits of freight carriers and UCC operators in the cases of fluctuating demand of customers. The evaluation on the multiple criteria was done including reducing delivery costs and CO₂, NO_x and SPM emissions. Rabe et al. (2018) applied a discrete event simulation to evaluate an UCC for distribution in Athens. They concluded that the simulation showed that utilizing UCCs lowered the number of tours needed to meet the customer's demands and decreased the required distance.

Joubert (2018) applied the multi-agent transport simulation (MATSim) for evaluating

the relocation of an urban container terminal in large scale scenarios in Cape Town, South Africa. Results showed that the simulation provided insights about how specific operators and the public at large will be influenced, both from an overall vehicle-kilometres travelled point of view and the change in travel times.

Jlassi et al. (2017) evaluated the regulatory policies including the vehicle size and time windows in city logistics using a multi-agent simulation in Paris. They tested four scenarios and discussed the simulation results from various viewpoints of number of vehicles, emissions of CO₂, NO_x and SO₂.

Taniguchi et al. (2018b) demonstrated how multi-agent simulation can be used for evaluating a combination of city logistics policy measures focusing on consolidation centres, green management and parking management. They pointed out that in public-private partnerships (PPP), multi-agent models will play an important role for evaluating city logistics policy measures based on data. Sharing data from both the public and private sectors is essential and interaction between both sectors is necessary to find better solutions using the results provided by multi-agent simulation.

Multi-agent models can be used for multi-stakeholder decision making based on this modelling approach. Le Pira et al. (2017) applied integrated models of discrete choice models (DCM) with agent-based models (ABM). These models consider stakeholders' heterogeneous preferences and simulate their interactive behaviour in a consensus building process. They pointed out that the integrated models of DCM and ABM can overcome their weaknesses, since it is grounded on sound microeconomic theory providing a detailed (static) stakeholders' behavioural knowledge, but it is also capable of reproducing agents' (dynamic) interaction during the decision-making process. Lebeau et al. (2018) presented the multi-actor multi-criteria analysis (MAMCA) as a method which structured the consultation process of stakeholders in city logistics. They tested this approach in a workshop in Brussels and concluded that the methodology allowed the authorities to identify the priorities of the stakeholders in City Logistics, to guide the discussion towards a consensus and to provide inputs for an eventual adoption of strategies. Gatta et al. (2019) applied an interactive MAMCA for analysing off-hour delivery (OHD) solutions with stakeholders in Rome. They pointed out that stakeholders prefer a solution where OHD are jointly implemented together with one or more urban consolidation centres.

3. Data sharing between public sectors and private companies in some cities in Europe, Japan and Australia

3.1 Overview

The data sharing between public sectors and private companies is important for modelling, planning and evaluating policy measures related to city logistics. Recently ITS (Intelligent Transport Systems), ICT (Information and Communication Technologies), and IoT (Internet of Things) allows private logistics companies to obtain precise data on movements of vehicles and goods, location of depots and demands for delivering goods. Public sector traditionally owns data on traffic congestion, crashes, emissions of CO₂, NO_x and PM, and infrastructure provision. Data sharing within stakeholders is beneficial for understanding the current status and planning sustainable urban freight transport in the framework of public-private partnerships. However, there are issues of confidentiality of logistics companies, costs of collecting data, regulations by law and lack of tools for analysing data.

To exchange knowledge and discuss these topics, we conducted a workshop online on 19th November 2020 on “Data sharing between public sectors and private companies for developing policies in city logistics.” Twelve professors and researchers who are actively doing research in city logistics area participated in the workshop from France, Sweden, The Netherlands, UK, Australia and Japan. We had six presentations and intensive discussions on the issues and barriers, benefits for stakeholders, framework associated with data sharing between public and private companies for city logistics. The following sections highlight essential points on the topics based on case studies in France, Sweden, The Netherlands, UK, Japan, and Australia and discussions in the workshop. We also had an interview to a person who are in charge of urban freight planning in City of Rotterdam, on data sharing with private companies in The Netherlands.

3.2 Current status, issues and benefits

The data sharing between public sectors and private companies is essential for understanding the current status of urban freight transport. National and local governments try to encourage data sharing relating to urban freight transport. However, there are issues and barriers in executing practice. Moschovou et al. (2019) pointed out that the main barriers met in sharing freight data are legal barriers, resource barriers, competition barriers, and institutional barriers. Legal barriers mean the existence of laws that restrict data sharing. Resource barriers encompass the restrictions in funding and the lack of resources. Competition barriers are derived from the confidentiality of business in private companies. Institutional barriers indicate the limitation of sharing data between various organisations. In spite of these issues and barriers, some good examples of freight data sharing are observed in several countries in Europe, Japan

and Australia, which are highlighted below.

In Rotterdam, the Netherlands, the data sharing for improving urban freight transport is performed among City of Rotterdam, 56 private companies, and two universities (Duin, 2020). The covenant of data sharing between City of Rotterdam and 56 companies was signed in 2020, including receivers, transporters, shippers, retailers, financial service providers, vehicle manufacturers and think tank. Figure 3.1 shows the data sharing scheme in Rotterdam. Universities take part in carrying out urban freight flow simulation using the data provided by private companies.

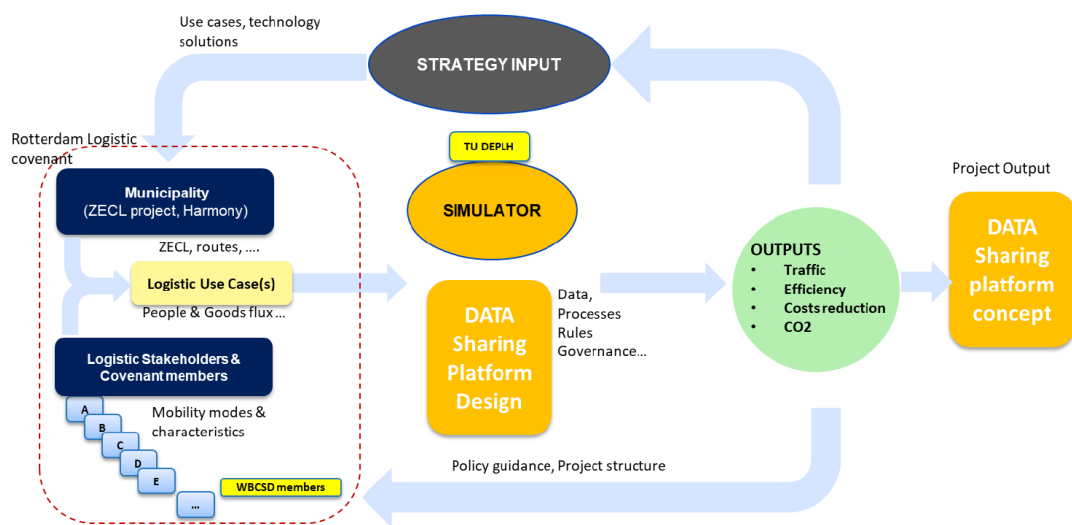
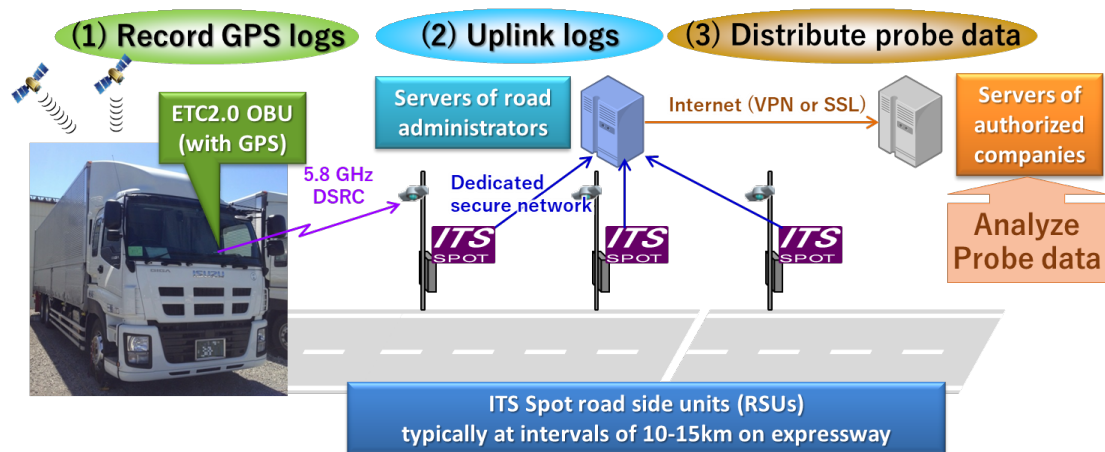


Figure 3.1 Data sharing scheme in Rotterdam (Source: City of Rotterdam)

In Japan the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) collect probe data of vehicle movements using ETC2.0 (Electric Toll Collection 2.0) on-board devices and ITS Spot roadside unit (Figure 3.2) (Taniguchi, 2020b). These data include the traffic of passenger cars and freight vehicles. The collected data of freight vehicles can be used by logistics companies for applying to vehicle management and improving safety driving (Figure 3.3). This initiative started in 2018. Benefits for logistics companies to use ETC2.0 data is; (a) less expensive compared to the case of setting up on-board devices and communication systems by themselves and (b) standardised data format is already given by data provider and easy to use ETC2.0 data for the vehicle management. Figure 3.4 shows an example of truck routing data by ETC2.0 which can be used for optimising the truck routing and scheduling as well as reducing emissions of CO₂, NO_x and SPM (suspended particle material).



Probe data:

- **Travel record** : time, position (longitude, latitude), speed
→ stored every 200m, or every 45° change in the driving direction
- **Behavior record** : time, acceleration, speed
→ stored when the acceleration exceeds the threshold value

Figure 3.2 ETC2.0 Probe data collection in Japan (Source: MLIT)

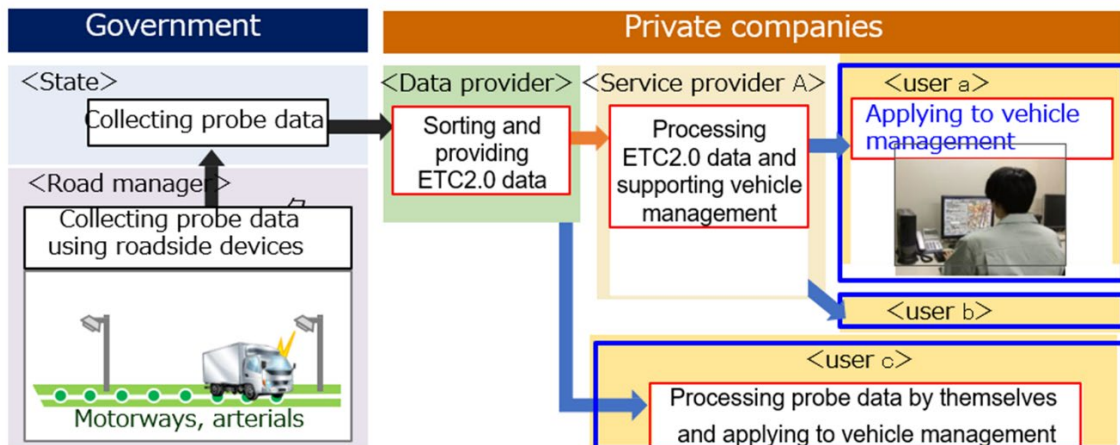


Figure 3.3 Sharing ETC2.0 data between government and private companies in Japan (Source: MLIT)

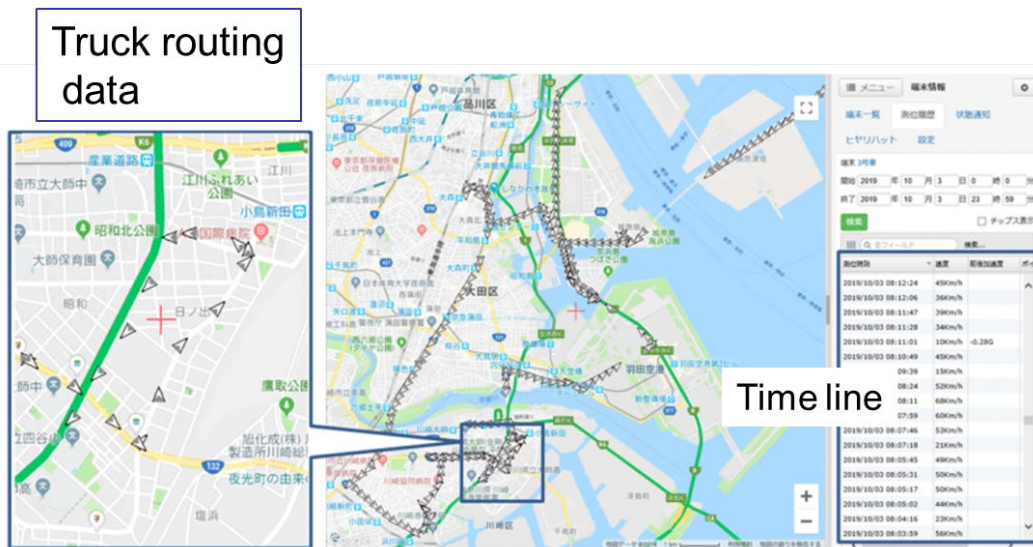


Figure 3.4 Example of truck routing data by ETC2.0 in Japan (Source: MLIT)

In Japan the framework for data sharing between public sectors and private companies is given by Basic Act on the advancement of public and private sector data utilization (2016) illustrated in Figure 3.5. The Act is to determine the responsibilities of the state, local public entities and private companies by providing for basic principles with respect to the advancement of the appropriate and effective use of public and private sector data.

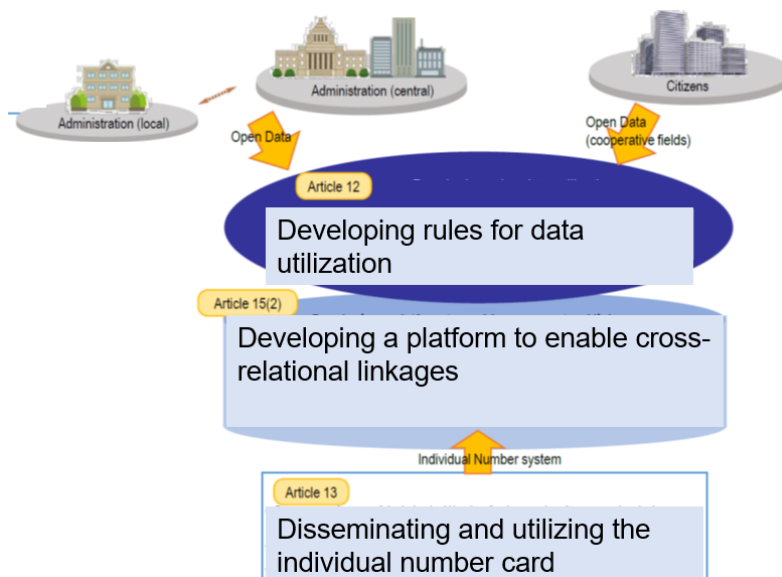


Figure 3.5 Basic Act on the advancement of public and private sector data utilization in Japan (2016) (Source: Cabinet Office)

In France, there are some examples of public-private exchange of information for public interests in City of Paris, Lyon and Saint-Etienne. In Lyon-Saint-Etienne area, two public bodies and two private companies and four research units participated in ELUD (Efficacité de la logistique urbaine alimentaire durable) project (research based) (Gonzalez-Feliu, 2020). They carried out route data sharing, spatial data sharing, use of standard research-based demand and supply estimation tools. Some results supported public and private decision making (Palacios-Arguello et al., 2018; Gonzalez-Feliu, 2019). Open data are also available and spatial and functional data are used to support public-private collaboration in decision making via a web-based tool (Gonzalez-Feliu, 2017).

In Australia, Bureau of Infrastructure, Transport & Regional Economics (BITRE) made Non-Disclosure Agreement with some transport companies and obtained truck GPS (Global Positioning System) data (Thompson, 2020). The government uses these data for understanding the traffic congestion and analyse them for better traffic management and infrastructure provision.

In UK data sharing and information sharing is carried out within the Freight Quality Partnership for urban freight transport (Wainwright, 2020). For example, Central London Freight Quality Partnership (CLFQP) with Transport for London (TfL) and private sector organisations started in 2006 for central London. TfL executed Street space initiatives which aims at creating more space for people for safely walk, cycle, scoot, or wheel in response to the COVID-19 pandemic in 2020. Information on the change of road space usage, including street closure, footway made wider, restricted through traffic is shared with private companies, since this type of information is useful for smooth delivery of goods.

In Sweden, sharing data, knowledge and visions is performed between public and private sectors. For example, in Gothenburg some industry and public data are combined for better understanding and planning of transport infrastructure (Flodén et al., 2020).

3.3 Discussions

There is a large variety of data sharing between public and private sectors for urban freight transport in different countries due to laws, cultures, and businesses environment.

Collaboration in data sharing is beneficial for both public and private sectors in the context of public-private partnerships in urban freight transport. For public sectors, they can utilise real data of logistics activities of private companies for developing policies on urban freight transport. For private companies they can enjoy lower costs for data collection and usage. If data are already provided in standardised format, they can easily use data for collaborative delivery with other companies.

Regarding the confidentiality of private companies' data, the covenant between public

sectors and private companies is effective to allow the public sector to use a company's data but not open them to other competitive companies. This type of covenant is needed to ensure the confidentiality of private companies. If some companies agree to operate joint delivery system, for example, it is welcome to use data of multiple companies who take part in the joint delivery systems. Therefore, the clear agreement and covenant promote reliable and effective initiatives.

In Sweden, when private data are given to public sectors, the data may be legally recognised as "official records" which mean to be accessible for the public. This may be a reason for private companies not willing to be involved in data sharing with the public sector. Shared data should be under the trusted party and the public authority may not be a trusted party, if the public authority need to open the shared data coming from private companies to the public.

Data sharing between public and private sectors is usually volunteer based schemes. In certain cases of The Netherlands, Japan and Australia volunteer-based data sharing is successfully carried out. The incentives for private companies to be involved in data sharing with public sectors and other private companies may be lower costs for collecting data, access to better software for analysing data, and use of standardised format of data.

In city logistics data sharing is a part of public private partnerships (PPP) between stakeholders. Therefore, based on data sharing, the stakeholders are able to understand the current condition of urban freight transport, analyse the policy measures, implement them and evaluate their effects. The total activities in PPP should be well coordinated. In this sense the limitation of data affects the analyses and results and then sharing data can overcome the limitation of data of a single entity.

Regarding the quality of data, somebody or some institutions should guarantee the quality of data. The standardisation of the method for collecting and processing data is critical for analyses. Usually, we face missing data in spatial and temporal data of urban freight transport. How we can extrapolate the missing data is an important problem for obtaining the good results with higher accuracy.

In the time of COVID-19 pandemic, data sharing is important between stakeholders, since the worldwide pandemic is the first time, and we face the difficulty to estimate the sudden change of demands of customers. Also, as there is uncertainty of estimating the behaviour of customers in the pandemic, we need to share data and experience associated with urban deliveries.

4. Recent advances of city logistics in Europe, Japan and Australia

4.1 Overview

This section presents discussions and perspectives on the recent advances of city logistics for sustainable and liveable cities based on the final workshop organised by FFJ/Michelin Foundations on 25th January 2021. Nine speakers from Europe, Japan and Australia participated in the workshop and presented recent advances of the research in modelling, planning and evaluating city logistics and discuss issues and innovative solutions associated with urban freight transport for sustainable and liveable cities.

4.2 Current status, issues and innovative solutions

4.2.1 Japan

Taniguchi (2021) presented the framework of the integrated platform of city logistics shown in Figure 4.1. In the integrated platform the information systems in the cyber space and the real vehicle operations in the transport network can be integrated and multimodal freight transport is used. The integrated platform can be achieved by the support of emerging technologies of ICT, ITS, IoT, big data, AI, autonomous vehicles, and robots as well as the public-private collaborations including the use of urban consolidation centres, multimodal freight transport and data sharing.

The emerging technologies allows us to take a data driven approach. Figure 4.2 illustrates the data driven approach for city logistics using multi-agent simulations. We can collect data on demands of customers, vehicle types, and traffic conditions using IoT sensors and process them. Then we can analyse the behaviour of stakeholders of shippers, freight carriers, administrators, and residents using the behaviour models and AI or machine learning techniques. The analyses involve the response of logistics companies to the policy measures implemented by the administrators and the effects of applying autonomous vehicles for last mile delivery. Finally, the evaluation can be done on the output of vehicle movements, emissions of GHG and NOx, energy consumption, and costs.

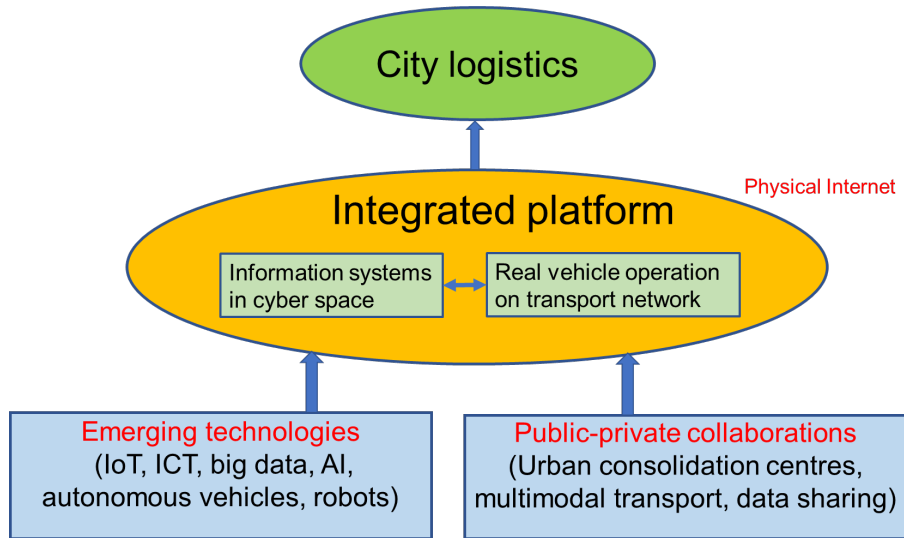


Figure 4.1 Framework of integrated platform of city logistics

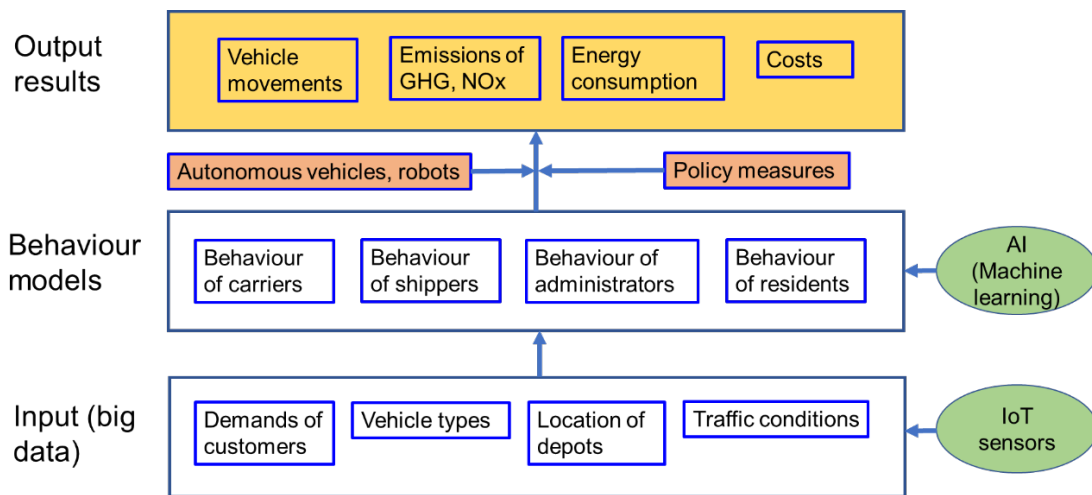


Figure 4.2 Data driven approach for city logistics using multi-agent simulations

The multi-agent simulation (MAS) using machine learning helps to overcome the complexity and ambiguity of predicting the future benefits of stakeholders, since MAS incorporates the interactive behaviour of stakeholders in dynamic domain. Firdausiyah, Taniguchi and Qureshi (2019) assumed the interaction between stakeholders in city logistics shown in Figure 4.3. They analysed the behaviour of stakeholders in case of joint delivery systems using MAS and found that the adaptive dynamic programming (ADP) based reinforcement learning gives more profits to UCC operators than using the conventional Q-learning and provides better results in reducing negative environmental impacts as illustrated in Figure 4.4. It means that changing the UCC fees considering the behaviour change of freight

carriers of choosing UCC or direct delivery using ADP based reinforcement learning provide better states for not only UCC operators and freight carriers but also the society at large. MAS has a good potential for the real-time adaptive management of city logistics in the integrated platform.

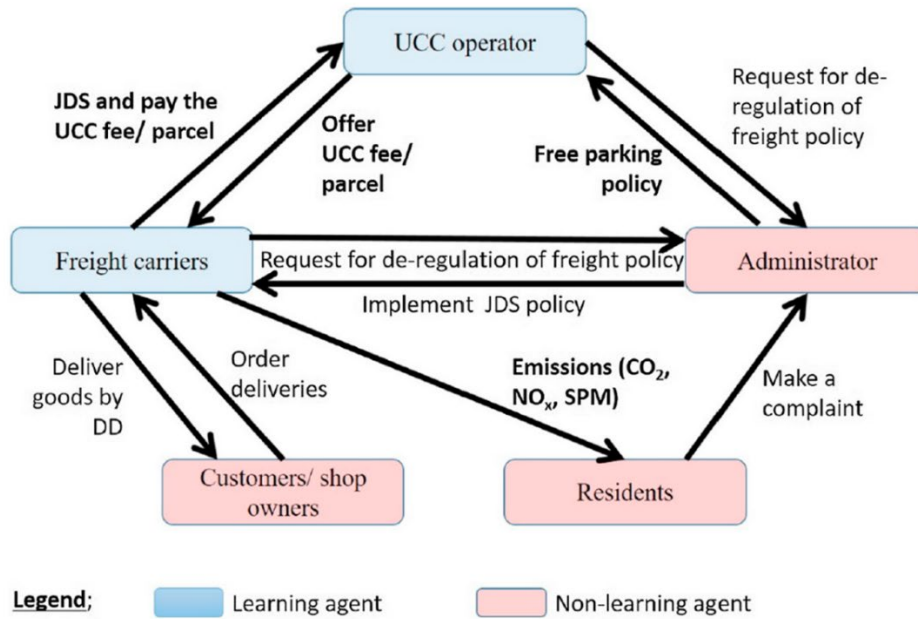


Figure 4.3 The interaction between stakeholders in city logistics (Firdausiyah et al., 2019)

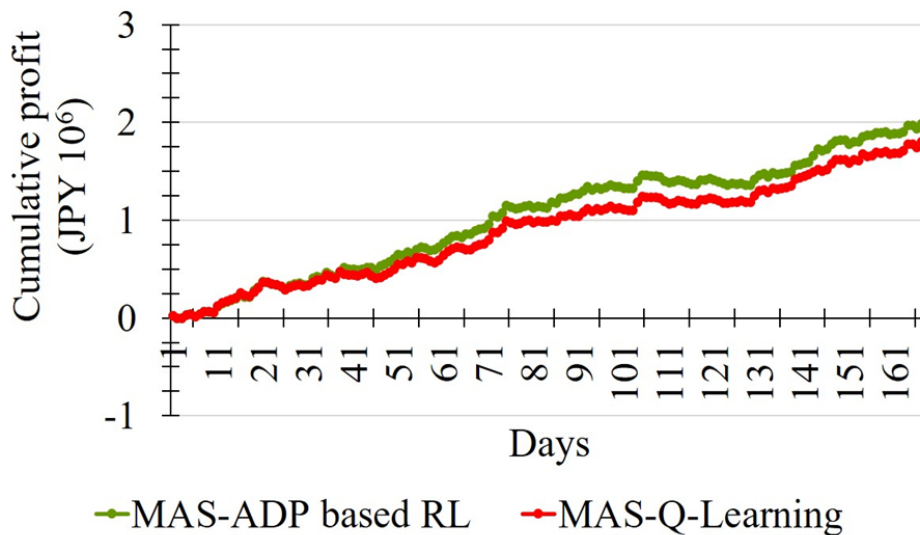


Figure 4.4 UCC operator's profit by multi-agent simulation (MAS) using adaptive dynamic programming (ADP) based reinforcement learning (RL) and Q-learning (Firdausiyah et al., 2019)

Figure 4.5 demonstrates the experiments on autonomous vehicles in Fujisawa city, Japan. The system can provide good services to customers such that they can receive their commodities within the designated arriving time windows of 10 minutes and the information will be given in their smart phone when autonomous vehicle is approaching the delivery point. Customers are allowed to identify any location where they hope to receive their goods.



Figure 4.5 Experiments on autonomous vehicles for last mile delivery (Fujisawa city, Japan, Source: Yamato)



Figure 4.6 Experiments of delivery robots in Keio University Campus, Japan (Source: ZMP)

The possible benefits of using autonomous vehicles for urban distributions are:

- (a) Reduce the total costs of the initial costs and running costs, since no drivers are needed for fully autonomous vehicle operations.
- (b) Provide a flexible system to meet with the rapid change of demands by customers.
- (c) Solve a problem of shortage of drivers.
- (d) Avoid a re-delivery due to the absence of receivers.
- (e) Provide a better service such as deliver goods anywhere, anytime at short time windows.
- (f) Provide a new service of delivering goods at a meeting point on streets or following a walking person.
- (g) Lower risk of infection due to contactless delivery in the pandemic times.
- (h) Connect with other transport modes of trains, barges, and drones.
- (i) Carry out multiple tasks including watching elderly people, disinfection spraying, cleaning.

There are also issues of using autonomous vehicle for urban delivery, which should be overcome.

- (a) High initial costs of purchasing autonomous vehicles or robots.
- (b) Acceptability of customers and citizens in terms of price, reliability, safety and security.
- (c) Regulations on the size, speed, payload of autonomous vehicles, and going on sidewalk and stopping locations on streets.
- (d) Concern about taking away jobs from drivers.
- (e) Limitation of range and payloads of autonomous vehicles and robots.
- (f) Location of micro hubs or moving hubs for two echelon delivery systems.
- (g) Provision of infrastructure of charging stations of electricity, and smooth surface of pavement
- (h) Appropriate stopping points on roads.

Regarding the collaborations between stakeholders, the joint delivery systems using urban consolidation centres (UCC) (Taniguchi and van der Heijden, 2000) are implemented in Tokyo. Figure 4.7 shows an example of UCC in Tokyo for the multi-tenant buildings (MTB), Tokyo Sky Tree Town, which started in 2012. In this case three UCCs are set for delivering goods to the MTB where shops, restaurants, offices, schools, and aquarium are located. Multiple freight carriers drop off their goods at UCCs and a single freight carrier deliver goods to MTB and final destinations of shops, restaurants etc. within MTB. This freight carrier was involved in designing the goods distribution systems within MTB including the loading/unloading space, elevators, information systems from the beginning of planning MTB which was helpful for smooth and effective operations of logistics activities.

Figure 4.8 illustrates the collaborations between stakeholders who are participating in the joint delivery systems with UCC. The developer (owner) of MTB is responsible for the good environment within and outside MTB and they financially support the joint delivery systems. As a result, the system achieved the lower UCC fee by 33-58% than other cases in Tokyo area, which freight carriers need to pay to the UCC operator. Note that the UCC operator is the same freight carrier who carry goods from UCC to MTB. The business model of supporting UCC is helpful for continuing the joint delivery systems. Tokyo metropolitan government gives advices on legal issues, although they do not provide subsidies.

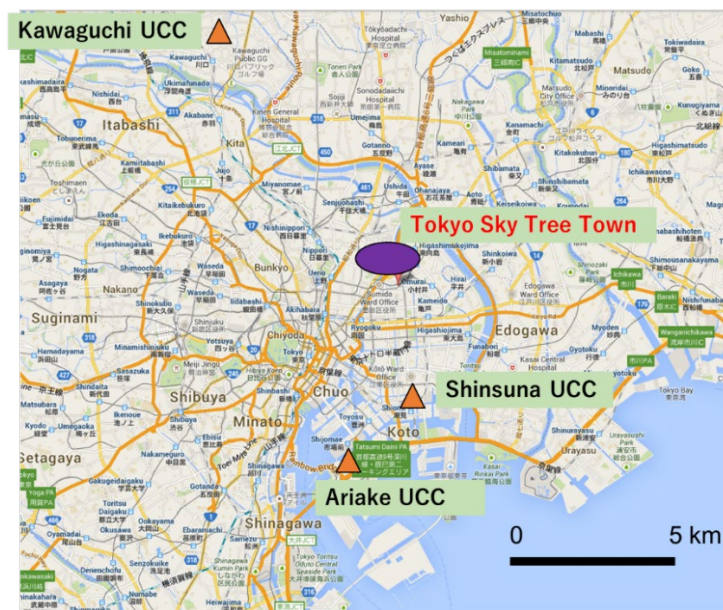


Figure 4.7 Multi-tenant building (Tokyo Sky Tree Town) and 3 UCCs in Tokyo (Taniguchi, 2021)

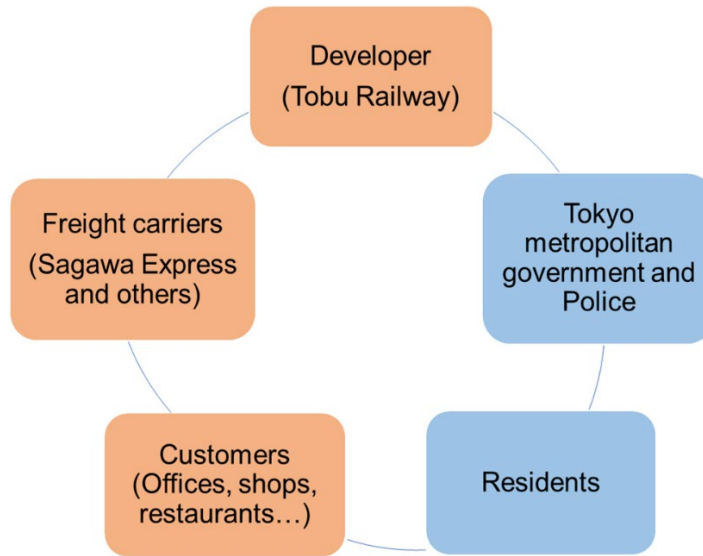


Figure 4.8 Collaboration of stakeholders for the joint delivery systems (Taniguchi, 2021)

Figure 4.9 demonstrates the reduction of number of trucks due to the consolidation of goods at UCCs. The total number of trucks used per day with UCC was reduced to 337 from 800 without UCC by 58%. At each UCC the number of trucks was substantially decreased to 2 from 140 at Shinsuna UCC, 3 from 230 at Ariake UCC, and 2 from 100 at Kawaguchi UCC, but direct delivery to MTB by 330 trucks remained mainly because of the requests from shop owners etc. This reduction of number of trucks can contribute to alleviate traffic congestion. As well, the CO₂ emissions were also reduced by 22% from 3,273 CO₂ ton/year to 2,532 CO₂ ton/year.

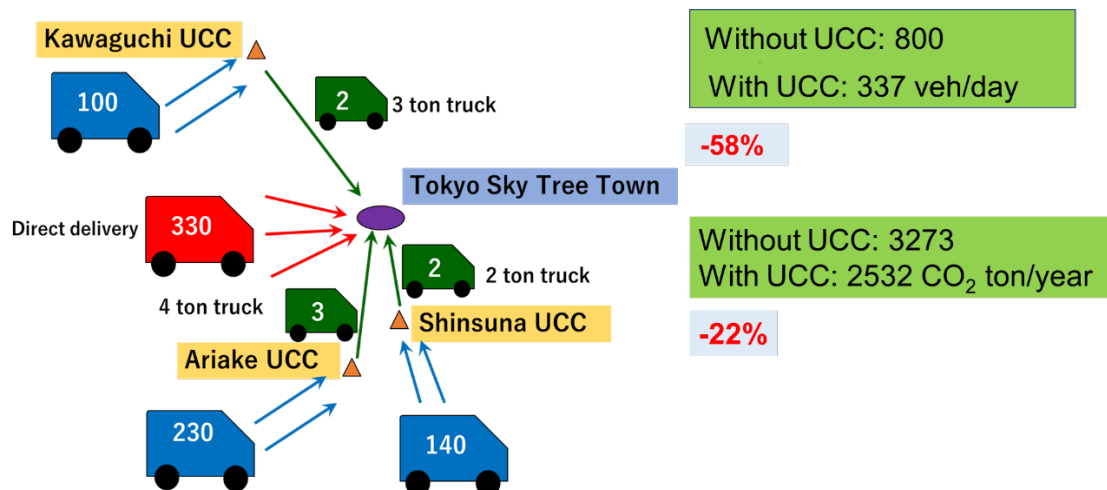


Figure 4.9 Reduction of number of trucks by the consolidation at UCCs to Tokyo Sky Tree Town (Taniguchi, 2021)

Dupas, Taniguchi, Dechamps and Qureshi (2020) calculated the effects of integration of four UCCs for three MTBs including Tokyo Sky Tree Town in Tokyo applying multi-commodity flow models (Figure 4.10). Figure 4.11 depicts the integration of UCC which allows the goods flow between UCCs and from any UCC to any MTB. Another collaboration between freight carriers is the pooling of goods which allows them to use the same trucks for delivering parcels to the same destinations. Figure 4.12 highlights effects of the pooling of goods and the integration of UCCs. This figure indicates that both the pooling and the integration are effective in reducing the total distance travelled by pick-delivery trucks. The total distance with the full integration was reduced by 18.3% in the case of no pooling and that with the pooling was reduced by 11.7%. The total distance with the pooling and full integration was reduced by 50.1% compared to the case without pooling and integration. Therefore, the collaborations between freight carriers by sharing the capacity of trucks and UCC are effective to decrease the total distance travelled which leads to the cost saving and the improvement of environment.

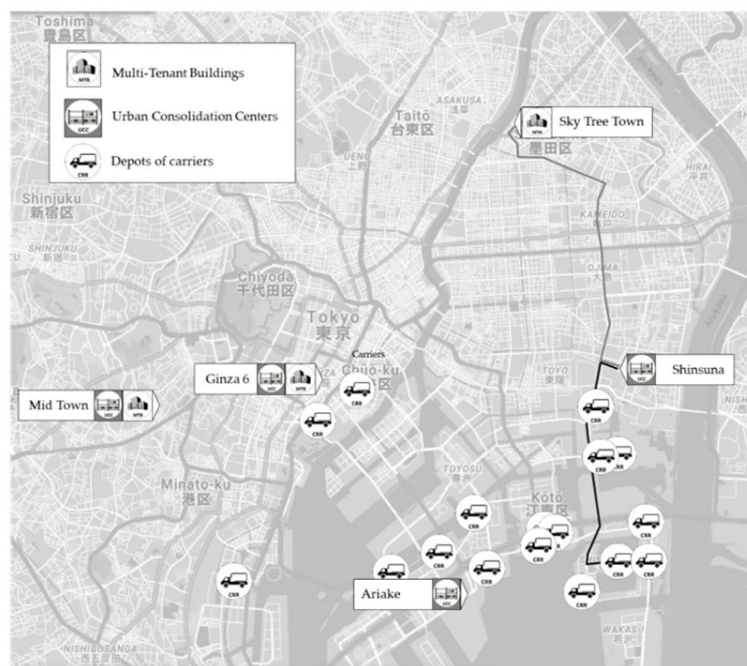


Figure 4.10 Location of three multi-tenant buildings, four UCCs and depots of freight carriers (Dupas et al., 2020)

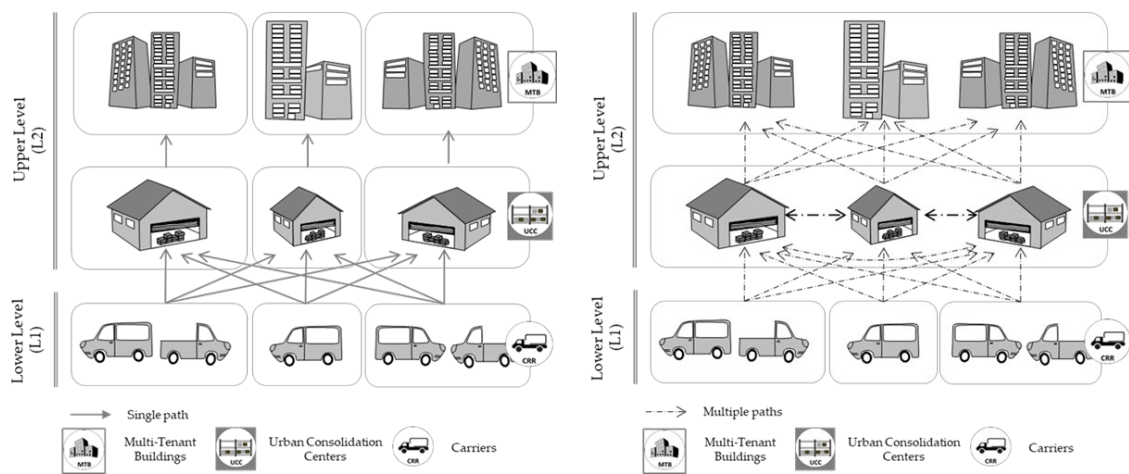


Figure 4.11(a) No integration of UCC

(b) Full integration of UCC

(Dupas et al., 2020)

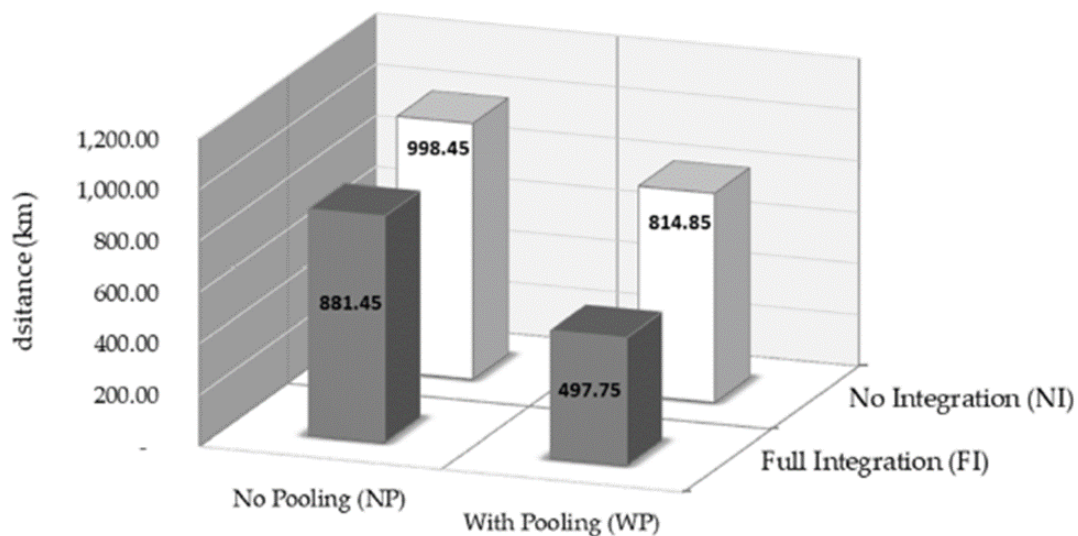


Figure 4.12 Change of distance travelled with the effects of pooling of goods and integration of UCCs (Dupas et al., 2020)

As concluding remarks, Taniguchi (2021) pointed out:

- (a) The integrated platform for combining information systems and real operation plays important role for optimising the urban freight transport systems.
- (b) Emerging technologies including ICT, ITS, IoT, big data, AI, autonomous vehicles, and

- robots help collecting precise data and analysing them using machine learning.
- (c) Advanced modelling with multi-agent simulation provides a strong tool for the adaptive management of city logistics.
 - (d) Public-private collaborations including UCC, and data sharing are essential for sustainable city logistics.

4.2.2 France

Dablanc (2021) presented innovations in city logistics in the case of France. According to the comprehensive urban freight survey in France, one delivery or pick-up is carried out per week. On the vehicle type, smaller vehicles or cargo bikes are used in urban areas. Urban freight data are still missing. In particular no plate-reading cameras are used in France on traffic/parking enforcement. Provision of data from freight operators is only emerging.

Regarding pick-up points of parcels, “home and in hands” is the first (27%) and “in a pickup point” (21%), “in mailbox” (15%) and “to doorman” (12%) follows in 2018. Pickup points in small stores show a new trend of receiving form of goods in urban areas.

CO₂ emissions from urban freight decrease 18% between 2004 and 2014 according to the official carbon footprint assessment of City of Paris.

Low emission zones (LEZ) are popular policy measures in EU, but in France implementing LEZ is later and slower than in other European countries. For greater Paris metropolitan wide LEZs are introduced in 2019 but it is difficult to enforce the regulations to vehicles, since no permission of using cameras is given for automatic enforcement until 2021. Only 70 municipalities out of 130 signed to agree the regulation.

The cycle logistics using cargo bikes is substantially increasing in large cities. In the COVID-19 pandemic time the access to bike lanes is the main advantage.

The electric vans increased only by 10% much slower than in electric cars by 159% in 2020.

Electric freight barges for the river Saine in Paris are used between the west port and the central Paris. The barges deliver cargo bikes with the parcels and pallets to the shops in central Paris and carry back electric waste on the way back.

Automated delivery vehicles of follower robots and drones have been tested in 10 areas, for example Paris and Montpellier in France. They discuss the reliability and acceptability by citizens of automated delivery vehicles.

Large scale multi-story logistics hotels were built in Paris and Lyon. These facilities are used for multi-purposes of logistics, retails, residential and offices. These were renovated from former industrial/rail areas or parking buildings. These facilities are located along with the peripheric road allowing the transshipment and inventory of goods. Small-scale logistics

terminals in underground municipal car parks are also located in the city centre. Two types of facilities are effective for providing the connecting points of long-haul transport and the last mile delivery in the city centre. Cargo bikes are often used for the last mile delivery of short distances.

Dupas, Deschamps, Taniguchi, Qureshi and Hsu (2021) presented innovative city logistics systems with UCC in Bordeaux. They assumed locations of five urban consolidation centres (UCC) in the peripheral area and three proximity logistics spaces (PLS) in the city centre. Two out of five UCCs and two out of three PLSs are operated in reality. Parcels are transported and consolidated in UCC and then delivered to PLS. From PLS to final customers cargo bikes are used for the distribution.

They calculated parcels flow using the multi-commodity network flow model, which was applied in the case study in Tokyo (Dupas et al., 2020). They found that the total distance travelled by small trucks from depots of freight carriers to UCC and from UCC to PLS was reduced by 51% with the pooling of vehicle capacities and the full integrations of UCC compared with the no pooling and partial integration of UCC. The results of the reduction of total distance travelled is like the case of Tokyo. In the cases of Bordeaux, the effects of pooling are larger than those of integration of UCC. They also highlighted the reduction of CO₂ emissions by 35%.

Gonzalez-Feliu (2021) discussed the Territorial Intelligence approach to support decision making in urban planning and food logistics. He proposed the methodology of Territorial Intelligence approach. This approach accounts for the logistics intensity and attractiveness of food supply in urban activities via Territorial Intelligence Indicators such as economic, environmental, socio-spatial and resilience and vulnerability indicators.

He applied the Territorial Intelligence approach in La Rochelle, France and demonstrated the important food demand generator indicating that the local fixed marketplace represents 40-60% of the food supply of the proximity retailers. HoReCa (Hotel/Restaurant/Café) sector has more homogeneous distribution in the city. He concluded that spatial analytics using Territorial Intelligence approach allow us to better understand current situations and can lead to a more relevant decision support methods and tools.

4.2.3 The Netherlands

Duin (2021) presented recent development of city logistics in the Netherlands. He pointed out that there are initiatives for zero emission urban logistics in the city centres by 2025 in the Netherlands. However, the city logistics systems face the serious challenges for the near future, since the systems are very diverse and difficult to change. Some sustainable urban freight systems have been proposed such as:

- (a) Electrification
- (b) Smart city---smart loading/unloading
- (c) Consolidation principles---urban consolidation centres, city hubs, parcel boxes (Figure 4.19)
- (d) Smart concepts---sharing logistics, physical internet

New booming is seen on the consolidation centres including the usage of moving mini hubs in the city where cargo bikes are used for the last mile delivery.

Light electric freight vehicles (LEFV) are used in urban delivery and they can replace 10-15% of all the van trips. Experiences of LEFV revealed that spaces for transshipments, and law for identifying the type of vehicles and position on the roads are needed. Experimenting in the Living Lab with LEFV leads to adaptation, knowledge and mind change.

Other solutions are considered in the research practice, including trucks on hydrogen, drone delivery for medicines, cargo hitching using passenger transport of buses, subways, trams, cargo bots using autonomous vehicles, sharing logistics, and physical internet.

4.2.4 Sweden and UK

Browne (2021) discussed the importance of stakeholder engagement and trust in data sharing for city logistics. We can find dramatic increase in data availability connected to urban freight and logistics, but many barriers exist to sharing data between private sectors and public authorities, for example, legal issues, competition, privacy and civil liberties, cost sharing etc. Some suggestions are given how they can be overcome through regulations, subventions, access privileges. Networks could be an important route. He presented examples from two networks, Gothenburg Freight Network “Godsnätverket Göteborg” (GG) in Sweden and Central London Freight Quality Partnership (CLFQP) in UK. GG started in 2005, being driven by the transport planning authority with 25 participants for cooperation, discussion, communication, development of measures for better urban freight transport. CLFQP is the public and private sector organisation which started in 2006 with the partnership of Transport for London (TfL). CLFQP tries to understand freight and logistics issues in central London for finding sustainable solutions for freight and services with sharing good practices. The members of CLFQP are some boroughs, TfL, Freight Transportation Association, and private logistics companies.

These two networks are related to topics, including information on future transport changes, changing the access arrangements for streets for result of decisions to increase space for walking and cycling, sharing information on changes of deliveries from changes in transport and logistics resulting from the COVID-19 pandemic.

Browne (2021) concluded as follows associated with the importance of stakeholder engagement.

- (a) A central activity that needs to form the part of strategy that increase data sharing in city logistics.
- (b) Builds trust, overcomes inertia within and between private sector organisations and public authorities.
- (c) Freight networks and partnerships offer a very helpful platform or starting point.
- (d) Potential to enable more rapid development of data sharing initiatives.
- (e) More is happening than we appreciate but, in many cases, this is not coordinated and retained.

Leonardi (2021) presented sustainable solutions in urban and logistics management based on European experiences. He showed a good example of tenant led joint logistics in the shopping mall as well as shopkeeper led business model of Binnenstadservice Maastrich in the Netherlands. These good practices demonstrate successful application of joint delivery systems with UCC in Europe.

He discussed Low Emission Zone (LEZ), which started for trucks in 2008, for vans in 2012, and cars in 2019 for keeping good air quality by controlling vehicles entering central London. From 2008, if entering the LEZ, all trucks with engines worse than Euro IV pay a charge of 100 or 200 £ per day. The impacts of LEZ for greater London and Ultra LEZ (ULEZ) for central London on the air quality in London was observed and the substantial reduction of PM10 can be seen. He showed the application of micro hubs for last mile delivery by cargo bikes and small electric vans, the use of waterways for supermarket retail logistics in Paris and London. He also highlighted the social benefits for city logistics solutions based on the TfL's FORS & Delivery & Servicing Plans in London (2008-2016), which depicts the substantial social benefits in terms of air quality and CO₂ emissions, infrastructure, noise, congestion, and accidents.

4.2.5 Australia

Thompson (2021) presented designing more efficient urban freight networks. He pointed out that the Improved vehicle loading, or the tonnes moved by km driven (*tonne-km / vehicle-km ratio*) is a key driver of emissions decrease in logistical field. This implies reducing the number of empty trips or km driven, increasing the use of available capacity in vehicles (which involves optimising three measures of capacity: volume, weight and space floor) and reducing the overall km driven by vehicles while delivering the same amount of goods. He discussed adapting Physical Internet (PI) principles for city logistics to transform the way physical objects are moved, stored, realized, supplied and used to improve efficiency and sustainability. The key elements of Physical Internet are open, integrated and shared networks,

Standardised and modular load carriers, and Information Technology (Crainic and Montrueil, 2016).

Thompson (2021) demonstrated case studies in Melbourne to show the shared pickup and delivery using parcel lockers and zero emission vehicles. It indicates the reduction of environmental costs by 75% and vehicle kilometres travelled by 50%.

5. Conclusions

This discussion paper presented the recent advances in planning, modelling, evaluating city logistics for sustainable and liveable cities. We discussed these issues base on some applications in Europe, Japan, and Australia. There are two important factors promoting city logistics, the use of emerging technologies, including ICT, IoT, ITS, big data, AI, autonomous vehicles, robots, and the collaborations between stakeholders who are involved in city logistics. The emerging technologies help urban freight transport to be more efficient, environmentally friendly and less energy consumption, safer, and secured through the process of optimising the urban logistics networks, as well as integrating the logistics system. The integrated platform is essential for reducing the costs and environmental nuisance and providing new services.

The collaborations between stakeholders are critical for successful implementation of city logistics initiatives. As public entities and private companies are involved in city logistics, the Public-Private Partnerships (PPP) are essential for achieving the common goals of city logistics. Data sharing between public sectors and private logistics companies are essential for identifying the issues and finding innovative solutions for urban freight and evaluating their effects in PPP. Modelling city logistics using the simulation and optimisation techniques base on the emerging technologies is essential to anticipate the effects of policy measures and benefits for each stakeholder to make proper decisions.

Further research is needed in modelling urban freight transport in the dynamic domain for the real time operations of freight vehicles. Sharing resources between players in city logistics should be deeply investigated for innovative solutions.

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