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Emerging Information and Communication Technologies: the challenges for the delivery loads using public logistics terminals

Francesco Russo[a] and Antonio Comi[b]*

[a] *Department of Enterprise Engineering, University of Rome Tor Vergata, 00133, Rome, Italy*
[b] *Mediterranea University of Reggio Calabria, 89100, Reggio Calabria, Italy*

Abstract

The paper reviews the literature on the developed and implemented solutions for delivering in inner-city areas pointing out the multi-echelon solutions and discussing the pros and cons in terms of operational and external costs, as well as exploring the opportunity supplied by the emerging information and communication technologies (ICTs) in optimising transfer operations.

Keywords: city logistics; urban transshipment; logistics terminals; information and communication technologies; Internet of Things (IoT).

1. Introduction

Many cities have started to understand and address the challenges associated with urban goods mobility issues by developing visions and strategies for urban goods transportation at a region or city level (De Marco et al., 2018; Holguín-Veras et al., 2020a, 2020b; Russo and Comi, 2020). In addition, comprehensive strategies for last mile delivery of goods at an inner-area level are often missing. Last-mile delivery of goods is a difficult issue to tackle, and in the next future is expected to accommodate concerns related to expected changes in the field, which are governed by a high level of uncertainty (Comi, 2021; Buldeo Rai and Dablanc, 2022; Campisi et al., 2023; Russo and Comi, 2023):

- small and frequent shop deliveries (i.e., limited availability of retail store surfaces in the inner areas due to high rent costs and just-in-time policies);
- e-commerce and omni-channel retailing;

* Corresponding author. Tel.: +39-06-7259-7061; fax: +39-06-7259-7061.
E-mail address: comi@ing.uniroma2.it

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- new ways to deliver products to customers, e.g., express deliveries, same-day deliveries, instant-deliveries;
- reverse logistics, both for recycling and products no longer desired or used (Rubio et al., 2019).

However, the different actions could not be implemented if they have not enough public (i.e., collectivity and operators involved) acceptability. Therefore, it becomes relevant to understand the costs incurred and how each action impacts on the operations of each involved actor, i.e., namely end consumer, transport and logistics operator, retailer, public administrator (Russo and Comi, 2016, 2018). In particular, urban consolidation centres (UCC), within a multi-echelon delivery system (Crainic et al., 2010; Wu et al., 2022, 2022; Zhang et al., 2019), are the most popular type of logistic platforms and one of the most implemented and studied initiatives (Allen et al., 2012; BESTUFS, 2007; Browne et al., 2011, 2005; Filippi et al., 2010; Musolino et al., 2019; Verlinde et al., 2012; Ville et al., 2013). These delivery systems have been widely ranked at the top when smart logistics solutions (Gogas and Nathanail, 2017; Teo et al., 2015), integrating transport-energy-ICT to promote sustainable development are implemented. Over the past decades, in various operational forms, they have emerged as a potential response to the ambitions of reducing the pollutant emissions caused by freight transportation in the last mile.

Therefore, public logistics terminals (such as UCC), located in areas surrounding a city, can be helpful in promoting cooperative freight transport systems and in reducing impacts due to goods movements. They can provide the government with information on the freight flows within the city areas through optimisation of loads as well as of the dimensions and typology of the vehicles used for freight operations. For example, usually, e-retailers, especially large-scale ones, adopt such a two(multi)-echelon delivery system: a warehouse located at the boundary of service areas (e.g., city boundary), delivery (city) hubs, and customer location. Warehouses serve the purpose of packaging orders and delivering shipments to the corresponding delivery (city) hub, while the delivery (city) hub receives and consolidates shipments from different warehouses/distribution centres and then delivers the shipments to customers in its location (zone). Furthermore, to address these issues, due to the increased limitations in urban freight transport including parking spaces, and the high costs of installing logistics infrastructures in inner city areas, two-tier distribution systems based on mobile depots were proposed (Oliveira et al., 2020).

In addition, telematics offers new opportunities for optimizing delivery. In particular, the evolution of emerging information and communication technologies (e-ICTs) has opened the way to developing and implementing new integrated and dynamic city logistics solutions and subsequently for identifying new frontiers of intelligent transport systems (ITSs). Transport and logistics operators should and could have technological solutions to improve the sustainability and efficiency of their urban freight transport operations, as asked by both international and local authorities. Solutions based on e-ICTs (Comi and Russo, 2022) can reduce the number of kilometres driven in urban areas, increasing safety and reducing environmental impacts and congestion (Croce et al., 2019; Russo and Comi, 2021). In this context, the development of innovative devices and services for smart routing capable of identifying the optimal delivery path and solving the vehicle routing/scheduling should be the future challenges of urban freight transport. Referring to driving and working time, which is one of the main costs supported by transport and logistics operators, these new tools could lead to a significant reduction in travel time, estimated in the case study presented by Russo and Comi (2022) by approximately 20%, compared to the average travel times.

In this background, the paper aims to review the literature on the developed and implemented solutions for delivering in the inner-city areas, pointing out the multi-echelon solutions, and discussing the pros and cons in terms of operational and external costs, as well as the opportunity supplied by e-ICTs in optimising transfer operations.

2. Modelling urban freight nodes

Public logistics terminals located in areas surrounding a city can be helpful in promoting cooperative freight transport systems, as well as reducing impacts due to goods movements. They can provide the government with information on the freight flows within city areas through optimization of loads and dimensions of vehicle used for freight operations, as said. These terminals (*nodes*) can have various functions such as the transhipment of goods, assemblage of products during distribution, warehouses and wholesale markets. In general, given a travel distance to cover for delivery/picking up, the operative costs related to a unit of freight decrease while the dimensions of vehicles (i.e., *vehicle type*) raise. On the other hand, the operative unit costs of a class of vehicle increase when freight transported decreases. Therefore, as summarised in Figure 1, it emerges that increasing the load and/or the distance, the unit operative costs decrease (Russo, 2001), however, the improper use of a class of vehicle can cause a significant increase of costs (e.g., *Qa / Qb*). Figure 1 shows the cost functions of two trucks of different net tonnage *Qa* and *Qb* (with *Qa* < *Qb*), at full load (lines *Qa / Qa* and *Qb / Qb)* and with cargo *Qa* for the truck of tonnage *Qb* (line *Qa / Qb*). Figure 1 also shows the cost trend for a truck of tonnage *Qb* that for a distance *d** loads only the quantity *Qa* and then in *d** makes a call from where it departs again at full load. In this case, there is an immediate reduction in unit costs. From this cost structure the urban transhipment activity is derived, i.e., the use of different types of trucks in relation to the distances to be covered. Similarly, it happens for the economic costs. Then, city logistics should point out the use of logistics terminals for optimizing urban goods movements promoting the transhipment:

- from heavy goods vehicles to medium ones;
- from heavy goods vehicles to light ones;
- from conventional light goods vehicle to environment-friendly vehicles (e.g., *p*-hybrid or electric);
- from eco-friendly vehicle to bike or on-foot delivery.

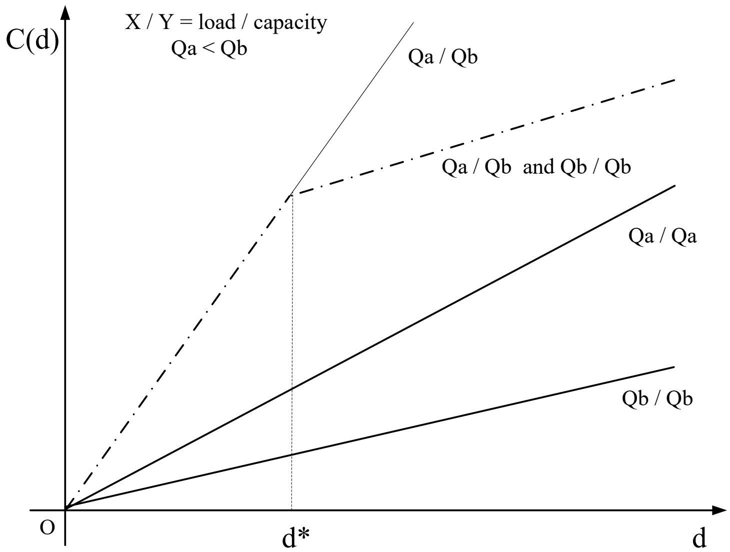

Figure 1 – Exemplification of cost/distance relationship for transporting in urban areas

Of course, at each transshipment point (i.e., logistics node), an extra operative cost germinates. The logistics network should also take into account the possible regulation implemented. For example, if a limited traffic zone (LTZ) is implemented, the necessity to use a surrounding terminal can derive.

Finally, transport costs can depend on the type of vehicle. In the first instance, it is possible to assume that the unit cost (i.e., cost for moving one item) for transporting within urban area is a linear function of distance *d* (no regulations are active):

- heavy goods vehicle (C_{HGV}),

$$C_{HGV} = c_{HGV} \cdot d \tag{1}$$

with c_{HGV} the unit distance cost for transport unit quantity of freight by a heavy goods vehicle;

- medium goods vehicle (C_{MGV}),

$$C_{MGV} = c_{MGV} \cdot d \tag{2}$$

with c_{MGV} the unit distance cost for transport unit quantity of freight by a medium goods vehicle;

- light goods vehicle (C_{LGV}),

$$C_{LGV} = c_{LGV} \cdot d \tag{3}$$

with c_{LGV} the unit distance cost for transport unit quantity of freight by a light goods vehicle.

3. City (pax and freight) flow control

The e-ICTs become every day larger and more popular (Atzori et al., 2010; Oliveira et al., 2022; Schroten et al., 2020) and can be introduced in the study of urban freight delivery systems. It is possible to identify four main classes of technologies that, at the current stage of development, push towards a smart city logistics: internet of things (*IoT*), block-chain (*BC*); big data (*BD*); artificial intelligence (*AI*). Automation, as well as other technologies that impact on the vehicle characteristics, as mentioned earlier, are not pointed out. For more details, refer to Taniguchi et al. (2020) and Comi and Russo (2022).

For example, in the context of delivering from the peripheral terminal (e.g., urban consolidation centres) to inner urban zones, the emerging technologies impact both on path choice to move along the intermediate customers (e.g., retailers or end consumers) and on delivery-bay choice to serve customer. In particular, *IoT* and *BD* can be considered the main emerging technologies impacting on path choice between two intermediate stops/delivery/customers (updating both of the path utility and choice model), even if *AI* could address developing advanced algorithms for better exploiting the opportunity offered by real-time info. On the other hand, *BC* allows to manage exchanges of values and protected/reserved data of the delivery (in this way, it is also called internet of values - *IoV*), while *AI* supports the route choice decisions.

On the other hand, city (passenger and freight) flow control can provide automatic control of vehicle access by activating rising barriers or bollards. Access can be also managed using CCTV (closed-circuit television), smart-cards or wireless communications. However, where barriers are considered visually intrusive, automatic enforcement systems such as plate recognition can be employed to ensure compliance.

In addition, control to access in limited traffic zones can be merged with delivery bay booking able to allow booked vehicles to access, or to control that only vehicles meeting environmental standards and weight constraints are allowed to access. In addition, the system can be used to control time widows and to provide daily, weekly, and periodic access reports. Sometimes systems can also interact with operators to manage and control daily fleet activity.

3.1. Deliveries in the inner areas

Telematics can support the new delivery system based on the concept of micro-consolidation centres (MCC). This scheme consists of the establishment of logistics platforms in the heart of urban areas where the consolidated goods are located before final delivery to the customer (Janjevic et al., 2013). From these spaces, last mile deliveries are executed using light-freight vehicles or soft transport modes (for example, on foot or by cargo bikes), through which congested or restricted urban areas can be accessed. Conceptually, MCC as well as nearby delivery bays (Russo and Comi, 2020) can be described as multi-echelon system where the inner platforms are the small-scale version of UCCs, which require minimal infrastructure and no storage equipment (i.e., same-day deliveries). Consequently, the investment is relatively low.

However, pushed by the opportunity to reduce the number of trucks in urban areas and to limit the issues related to e-commerce (i.e., delivery sprawl and delivery failure), a promising action could be the aggregation of delivery loads through the development of pick-up (parcel locker) systems which allow the optimisation of deliveries to end consumers (Lemke et al., 2016; Lin et al., 2020; Morganti et al., 2014; Rai et al., 2020; van Duin et al., 2020).

3.2. Management of delivery bay occupancy

The main idea is to have a delivery system able to book delivery bays, while real-time information and control measures are used to ensure effective operation. The advanced booking system could permit users to book delivery bays ahead of their arrival in the study area (e.g., some days before or some hours ahead or when just approaching the study area - last minute booking; (Comi et al., 2018b, 2018a; Thompson and Zhang, 2018). The system can suggest the best delivery bay closest to the customer location. Besides, since the control system involves a set of rules for dealing with real situations, functional/operating policies can thus be defined through the analysis of each possible situation, as well as on the basis of some predefined rules established by the administration for transport within the area, e.g., priorities to vehicles at full load or with many deliveries to be performed, or priority to new and more environment-friendly vehicles. Given that, despite the booking system, users can arrive later or earlier than schedules due to exogenous causes, when this happens, the system has to determine the access priority rules, in order to allow the user to perform his/her delivery operations.

A further evolution of this delivery system is the mobile-depot system (Verlinde et al., 2014). A mobile depot (MD) is a trailer fitted with a loading dock, warehousing facilities, and an office. The trailer is used as a mobile inner-city base from where last-mile deliveries and first-mile pick-ups are performed by electric cyclo-cargos. Therefore, MDs are a multimodal distribution system that consists of a truck that circulates through the city and allows light electric vehicles to deliver users (Arvidsson and Pazirandeh, 2017; Oliveira et al., 2020).

3.3. Traffic control and info systems: the generalised load

The urban traffic management and control (UTMC) system aims to improve traffic flow, to reduce journey times and delays, and improve road safety. This system monitors and controls traffic with signs, equipment, and other devices. Signs that provide information about speed limits, access restrictions, loading zones, and other regulations have been used to assist truck drivers (BESTUFS, 2007). The effectiveness of such signing can be enhanced with real-time traffic information and variable message signs.

In Barcelona, variable message signs display real-time access regulations on multi-use lanes (SUGAR, 2011). Signal coordination can also play a role, as most of such systems are calibrated for passenger vehicles. Thus, in areas with heavy freight traffic, adjusting the timing and progression to account for the speed and response time of trucks could improve the flow of traffic. Such a system can be used to provide specific equipment to specific routing guidance and real-time information on vehicle location, traffic incidents and changes in customer requirements. Similarly, navigation systems are able to determine the exact position of freight movements and the application of tracking and tracing systems can support logistics services, customers to get information about the actually position of loading (or the real-time occupancy) and helps to estimate the time when the expected delivery will reach them.

UTMCs consist of the following components:

- Urban Traffic Control (UTC) aiming
  - to coordinate traffic signal timings,
  - to control automated LTZ access,
  - to control multi-use bus line;
- information to drivers
  - via roadside signs, variable message signs (VMS),
  - by route guidance, which can encourage freight vehicle drivers to use the most suitable routes; real-time information provided can include
    - preferred routes,
    - vehicle height and weight restrictions,
    - access and loading regulations,
    - locations of goods vehicle parks (i.e., delivery bays);
  - by in-cab communication;
- journey-time measurement systems via automated number plate recognition technology.

3.4. Management of urban transfer hub and national logistics platform

To optimise urban flows, a hierarchical network (exploiting the opportunity to use transhipment as summarised in Section 2) can be implemented in which the distance class is used according to the requirements. The functional model is based, above all, on a macro-zoning of the urban area according to the characteristics for production and attraction of the goods vehicles and people for purchases, and their impact on the external environment. With reference, for simplicity of discussion, to a circular urban structure, macro-zoning is characterized by:

- *urban centre*, with maximum density of residents and tertiary activities on an urban and suburban scale; the road system is historical and multifunctional; it generally coincides or includes the historic centre; the urban centre can be broken down into, i.e., one or more pedestrian zones; one or more limited traffic zones (ZTL); rest of the urban centre;
- *first ring*, generally residential with local tertiary activities, whose main road network is characterised by

neighbourhood and inter-district roads and whose external delimitation consists of a main ring road;

- *second ring*, generally with low population density and a prevalence of secondary or tertiary activities with high soil consumption, characterised by a flow road or neighbourhood.

In this functional model, smaller urban nodes (i.e., transit points and nearby delivery areas) are foreseen for historic centres and pedestrian areas, i.e., small urban transshipment platforms in which dedicated personnel supports in sorting deliveries in the last mile (direct to the city centre); the goods are thus unloaded from arriving vehicles from the connecting logistic platforms, and loaded onto trolleys, electric vehicles, and bicycles for the final segment of distribution. The urban hubs are located in the second ring (logistic belt) and in the corridors of entry to the first ring (where distribution/consolidation centres are located) and the second ring (logistic axes). The structure of the flows of freight vehicles is therefore of the centripetal type, from the outside towards the centre.

Therefore, at the city level, a first hub can be foreseen to support the link between haulage transport and flows to / from the city (last mile transport). Different management strategies can be implemented to govern the freight flow from the hub to the city, as well as if one or more enterprises manage the process. In some countries, a national logistics platform is under development. For example, in Italy UIRnet is promoting the development of a National Logistics Platform to manage and control the transport among the main national freight nodes (i.e., freight villages, intermodal nodes, ports). Then, the connection between the national platform and the peripheral hub becomes relevant for the improvement of freight flows to/from cities. For example, the ICTs can reveal the vehicles directed to its area of interest and plan (including time slices for serving) all operations to be performed without human actions.

3.5. Management of urban logistics hubs

According to the distribution system and the macro-zoning of the city introduced in Section 3.4, the freight destined to the city can be intercepted at the city border (through a city hub) before reaching the final destination. In these freight nodes, that can be Urban Distribution/Consolidation Centre or mini-warehouses, the main function provided is the optimization of transport operation (management and control of delivery operations in terms of groupage of loads, delivery time, load, and more performing and smaller vehicles). No further actions on the freight are provided. The loads are transferred from heavy/medium good vehicles (more than 12 tons), coming from the border hub to the vehicles which are more performing to deliver in urban contexts (laden weight less than 3.5 tons). Tracing and tracking services can be also provided in order to inform users in real time on the status of their deliveries.

Then, to meet the high level of reservations implemented in the inner areas of a city, the freight, before reaching the final destination, a further transhipment can be done. The loads can be thus transferred to more environment-friendly vehicles (i.e., bike, electric vehicles) within transit points or nearby delivery areas (NDA).

4. Conclusion

There are many challenges in delivering in cities and especially in inner-city areas. In particular, in the context defined by smart city, where telematics contributes to solve real issues of its citizens. Users in their everyday life, face with some of the most recurring problems that the growth of built-up areas implies, such as impacts from freight transport systems. Reducing the impacts of delivering as well as the number of vehicles, the policies/measures that pushed towards optimization of loads are welcome. However, there are many issues due to their acceptability of operators with significant implementation issues. On the other hand, identification of the optimal routes for the distribution of goods involves considering the costs of driving and possible walking. This paper, in the context of smart city recalling the literature multi(two)-layer optimisation model that produces both driving and walking routes (in the limited traffic areas), evolves pointing out the opportunity offered by the emerging technologies in pushing advancements in methods and models for supporting operations, as well as for reducing freight distribution impacts, optimising the load. The reference city is the smart one, where the three fields of transportation, ICTs, and energy are working jointly to increase the quality of the city in line with Agenda 2030 (UN, 2015). The innovations pushed by e-ICTs (internet of things, block chain, big data, artificial intelligence) are identified in the light of people-centred solutions. In fact, delivery problem exploiting the emerging technologies allows to optimise the costs supported for optimizing the vehicle load, driving, as well as for walking efficiently using the data (BD^{PA} - i.e., owned by public administration - and BD^{TLO} - i.e., owned by enterprise) acquired by sensors (IoT^{PA} and IoT^{TLO}). The opportunity to implement such a multi-objective approach, comprehensive of an energy consumption/reduction, to location problem for designing nearby delivery areas as well as mobile depots has been focused, too.

Further research would include results on real test cases, to point out the average time and costs gains from its adoption, and the opportunity to extend the proposed framework to capture the opportunity offered by the digital twin, as well as in using coordination and cooperation (Zibaei et al., 2016; Gonzalez-Feliu et al., 2018; Gomez-Marin et al., 2020).

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