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AN ASSESSMENT FRAMEWORK TO SUPPORT COLLECTIVE DECISION MAKING ON URBAN FREIGHT TRANSPORT

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Abstract. This paper proposes a framework that supports the collection and classification of information about the features of a city relevant to Urban Freight Transport (UFT). The information is organized in a framework of 28 different layers that are then stored in a Geographic Information System (GIS) tool to enable efficient data retrieval and effective information graphical display. The resulting GIS tool thus represents a decision support system for UFT problems, providing decision makers and stakeholders with a wide range of easy to understand information aimed to support the identification and preliminary evaluation of UFT solutions. Moreover, by providing a standardized set of features and sources of information, the framework enables the comparison of different cities. To illustrate the benefits, prototypical real-scale tests based on the framework have been realized in two mid-sized European cities: Bergamo (North of Italy) and Luxembourg. For both cities, data were mainly collected from publicly available sources and organized according to the framework. The data and information collected have been used in collaboration with the stakeholders in order to identify the priorities of intervention and evaluate alternative UFT solutions. The real-scale applications confirmed the usability and effectiveness of the framework in engaging stakeholders and support the process of envisioning shared UFT solutions.

Keywords: urban freight transport, city logistics, stakeholder engagement, last-mile distribution, GIS, collaboration platform.

Introduction and research background

Urban Freight Transport (UFT) is one of the major research topics in the field of freight transportation (ERTRAC 2014), as it represents one of the ways indicated by the European Union to increase sustainability and liveability in urban areas (EC 2011).

Many solutions are nowadays available to mitigate the negative impacts of logistics activities in urban contexts (such as congestion, air pollution and noise), and the number is growing every day thanks to the current rates of technological development. The solutions that can be found in the literature vary from regulation (e.g., access restrictions) to time shifts (e.g., off-hour deliveries); from shifts in the transportation technology (e.g., electric vehicles, modal shifts) to changes in the supply chains (e.g., urban consolidation and distribution centres, delivery points for parcels) – Ambrosini, Routhier (2004); Russo, Comi (2011); Cherrett *et al.* (2012); Benjelloun *et al.* (2010). According to the databases of projects DOROTHY (Pino *et al.* 2014) and CIVITAS (Van Rooijen, Quak 2014), the solutions that found larger application belong to six typologies: freight consolidation, modal shift, access restrictions charging and environmental standards, lane and space use, alternative fuels/vehicles, B2C Solutions. These solutions are summarized in Table 1.

Even though many of the aforementioned solutions are quite consolidated, their application is frequently unsuccessful.

A recent systematic literature review in the field (Lagorio *et al.* 2016), reveals that the main reasons for these failures come from difficulties in retrieving data (Cherrett *et al.* 2012), uneven regulations, lack of enforcement, obsolete policies (Muñuzuri *et al.* 2012) and lack of harmonization between the regulations of neighbouring cities (Quak, De Koster 2007). However, the *lack of stakeholder involvement* – especially in the early stages of the decision making process regarding UFT – is considered as a major source of failure (Dablanc *et al.* 2011; Dablanc 2007; Lindholm 2014; Lagorio *et al.* 2016).

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Table 1. UFT solutions, which found larger application in the literature and in practice

Type of solution	Examples	References
Freight consolidation	Urban Consolidation Centres (UCC) / Urban Distribution Centres (UDC) (e.g., city of Padua)	Olsson, Woxenius (2014); Stenger *et al.* (2013); Lindawati *et al.* (2014); Alho, Silva (2015)
Modal shift	Use of naval/railway/airport terminals	Regué, Bristow (2013)
Access restrictions charging and environmental standards	Fuel/vehicle type restrictions, limited traffic zones, weight/height/width restrictions, road pricing, low emission zones, amount and source of noise (vehicle/handling equipment), night/off-peak deliveries	Quak, De Koster (2009); Holguín-Veras (2008); Bjerkan *et al.* (2014); Deflorio *et al.* (2012)
Lane and space use	Reserved lanes for transportation, loading-unloading bays optimization, use parking lots as hub areas	Anderson *et al.* (2005); Yang, Moodie (2011); McLeod, Cherrett (2011); Flamini *et al.* (2011)
Alternative fuels/vehicles	Use of low emissions, electric vehicles and bike delivery	Gruber *et al.* (2014); Schneider *et al.* (2014); Wang *et al.* (2014); Walker, Manson (2014)
B2C solutions	Use of pick-up shops and parcel lockers for parcel delivery to final customers	Ducret (2014); Morganti *et al.* (2014)

UFT projects involve a large variety of stakeholders (i.e., traders, transporters, traditional couriers, innovative and "green" transport companies), usually with contrasting interests (Lindawati *et al.* 2014). Even when all the relevant stakeholders are involved and their interests are aligned, stakeholders might not have all the correct information or skills to understand the nature and complexity of UFT problems, and they often overlook fundamental aspects (Lindholm, Behrends 2012). Moreover, stakeholder involvement requires a long-term perspective, time and effort to maintain interest and commitment and setting-up working groups is often fraught with obstacles and difficulties (Lindholm 2014; Witkowski, Kiba-Janiak 2014). It does not come as a surprise that, despite the presence of all the necessary stakeholders, many UFT initiatives do not go beyond the experimental stage.

To overcome these issues, several approaches dealing with stakeholder management have been proposed, e.g. Multi-Actor Multi-Criteria Analysis – MAMCA (Macharis *et al.* 2014; Gatta, Marcucci 2014) with the aim of evaluating different stakeholders' opinions at an early stage of the decision-making process. However, while trying to bridge and compromise the different stakeholders' interests, these methodologies may fall short in actually *engaging* the stakeholders, i.e., moving the stakeholders to a proactive and supportive attitude.

As a consequence, the aim of this work is not to replace such methodologies, but rather to complement them with a *framework* and visual *tool* designed to inform decision-makers and facilitate early stakeholder engagement in UFT projects.

The paper is organized as follows: first, we describe the structure and the sources of information of the proposed framework, providing a methodology that can be followed in other studies. Afterwards, we present the results of the application of the framework and the related tool on two cities: Bergamo (Italy) and Luxembourg. Finally, we draw the main conclusions and future developments stemming from our study.

1. Building the framework

In this paper we propose a framework that supports the collection and classification of information with the aim of enabling the assessment of a city along the most important dimensions related to UFT.

The goal of such a framework is threefold. First, it aims at providing a methodology to gather information relevant to UFT, exploiting publicly available information to the maximum possible extent, in order to overcome the well-known issue of the lack of data (Nuzzolo *et al.* 2015).

Next, considering the relevance of the stakeholder commitment with respect to the success of any UFT initiative (Holguín-Veras 2008), the framework aims at fostering and facilitating early stakeholder engagement in UFT projects, thanks to a visual and interactive tool, which draws upon the same previously gathered information.

Finally, the framework enables the possibility to perform comparative assessment between cities by providing common dimensions of evaluation. This is a crucial point as several researchers published in-depth case studies performed on single cities, thus generating a useful library of experiences (e.g., Álvarez, De La Calle 2011; Hesse 2004). Nevertheless, because of lack of a common framework, these case studies are often difficult to compare, as the time frame, data collection methods, and context of the cities are very different.

It follows that the framework proposed in this paper is tailored for a specific solution (Table 1), but it allows a high-level evaluation of a broad spectrum of solutions.

In order to devise the framework, the following building steps have been followed, as further described in the remainder:

– *Step 1:* identification of the main features of the city, which are relevant to UFT;
– *Step 2:* definition of the layers and sources of information;
– *Step 3:* development of an interactive tool to visualize the features to be used by decision makers and stakeholders.

1.1. Step 1: Identification of the main features

There are several features of a city to be analysed for a better understanding of UFT activities and impacts. On the basis of the literature, the most important features are the following:

1) *Morphology and historical heritage:* size of the area, presence of hills, rivers, canals, waterways that can create natural access barriers or make more difficult the distribution. Moreover, presence and extent of the historical centre that characteristics the higher touristic concentration and narrow streets (Pulawska, Starowicz 2014; Muñuzuri *et al.* 2005);
2) *Population:* total population and density, as most dense areas have the highest demand for goods, especially parcels (Gatta, Marcucci 2015);
3) *Land use:* location of residential, commercial or office zones that affects the demand and typology of goods during the day (Alho, Silva 2015);
4) *Infrastructures:* roads types, number of roads, roads dimensions, road tolls, which affect accessibility to the city (Lian 2008; Mohajeri *et al.* 2015);
5) *Typology and distribution of commercial activities* with different logistics requirements summarized in Table 2 (Kittelson, Lawton 1987; Joubert *et al.* 2010);

Table 2. Different typologies of commercial activities and the related transportation patterns

Type of shop	Transport pattern
Commerce bulky items (furniture, sport equipment, car, household appliances)	Low frequency, require larger vehicles
Commerce small items (apparel, accessories, kiosks, excluding supermarkets)	Medium frequency, suitable to smaller vehicles
Food	High frequency, can require refrigerated vehicles
HORECA (hotel, bar, restaurant)	Medium/high frequency, can require refrigerated vehicles
Health (pharmacies)	Very high frequency, can require refrigerated vehicles
High value (optician, jewelleries, excluding banks)	Low frequency, subject to robberies

6) *Transportation companies and logistics activities location*, which represent relevant points of origin of commercial traffic towards the city (Allen *et al.* 2012; Lüer-Villagra, Marianov 2013);
7) *Access restriction measures* such as weight restrictions or delivery windows, which affect accessibility of the city centres and concentrate private and commercial traffic in specific hours (Quak, De Koster 2009; Holguín-Veras 2008);
8) *Existing UFT infrastructures* such as freight terminals, urban consolidation centres.

These different features of the city have been rarely considered together. The reason is that they belong to different fields, such as urban planning, geography, logistics. However, since transportation is a sub-system in the broader city system, our framework proposes to consider these dimensions jointly.

1.2. Step 2: Definition of the layers and sources of information

In this second step, for each feature described in Step 1, we identified possible sources of information, giving priority to open data sources to extend the application of the framework to other cities. In particular, we substantially relied on Open Street Map (OSM) that has also the advantage to provide with automatic updates thanks to Application Programming Interface (API) routines. However, further sources have been considered in order to increase the reliability and quality level of the information (e.g., data from public authorities). In this respect, it is impossible to be in any sense exhaustive, since the availability of data and information depends upon the areas and cities considered. The two cases presented at the end of this paper illustrate how the different sources of information can be retrieved and combined.

With a view on making the framework user friendly to stakeholders and harmonized with the sources of data, we reorganized the features identified in Step 1 in 8 *categories* (Table 3). In this effort, we also followed INSPIRE, a European Directive (EC 2007), which aims at facilitating the sharing of spatial data between public authorities and improving accessibility. For instance, we split infrastructures into two categories: *road network* and *railway network and waterways* as the former is a capillary infrastructure while the latter is linear infrastructures (railways, rivers and canals).

Next, for each category we defined a set of *layers*. For instance, the category "access restrictions" was broken-down in the following layers: delivery windows, limited traffic zones, access restrictions and road barriers.

The final framework comprises of 28 layers, classified in 8 categories. The categories and layers are summarized in Table 3, which also reports potential sources of information. It is possible to underline the sparsity of the sources and the relevance of direct observation, thus supporting the need for a unified way to organize this information.

Table 3. Information used in the framework and sources

Category	Description	Layers	Possible sources
Morphology	Includes layers that serve as a background related to the morphology of the city, such as the presence of natural enablers or barriers to urban logistics (e.g., canals, rivers, hills)	Morphology	Google maps (terrain)
Administrative units	Related to the information representing municipality borders and historically relevant areas that may require careful consideration when UFT plans are devised	Municipality/city borders	OSM
		Historically relevant areas	Municipality development plan
		Neighbourhood/quarters	Municipality development plan
Society and commercial activities	Includes the information regarding the population density and land use (i.e., green, industrial, infrastructure, residential, residential/commercial, and tertiary). Also includes residential rent prices and information about the location and typology of commercial activities	Population density	Corinne land cover
		Land use	Municipality development plan
		Rent prices	Municipality, websites
		Shops (further divided as in Table 2)	OSM, municipality survey
Road network	Motor vehicles network (including bus lanes and other dedicated road), cycle network and pedestrian network are mapped in this category	Motor vehicles network	OSM
		Cycle network	OSM
		Pedestrian network	OSM
		Bus lanes	Municipality Geographic Information System (GIS)
Access restrictions	Access restrictions (or controlled access) schemes	Delivery windows	Municipality website, direct observation
		Limited traffic zones	Municipality website, direct observation
		Access restrictions (height/weight/width, fuel)	Municipality website, direct observation
		Road barriers	Municipality website, direct observation
Transportation facilities	Includes information about all the facilities (except for roads and railways) supporting the execution of urban logistics processes. Includes the location of Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG) stations, as well as electric vehicles charging points. Further, information about loading and unloading bays and parking slots. Finally, the presence of airports is considered in this category	Airports	OSM
		Alternative fuels stations	*mylpg.eu*, *cngeurope.com*
		Charging points	openchargemap.org
		Street parking	Municipality GIS
		Loading/unloading bays	Municipality GIS, direct observation
		Parking lots	OSM, yellow pages, Google maps
Delivery points and transportation companies/ facilities	Includes the location of the main transportation companies (express couriers and 3PLs) that regularly deliver the goods in the city. Further, contains specific logistics infrastructure such as UDC and city terminals is considered in this category	Parcel solutions	Various websites (couriers, operators, online retailers)
		Transportation companies/couriers	Yellow pages, various databases
		Logistic infrastructures (UCD, city terminals)	Municipality GIS, direct observation
Railway network and waterways	Includes data about railway and waterway networks	Railway network	OSM
		Tram network	OSM
		Water network	OSM

1.3. Step 3: Development of an interactive platform to visualize data and use with the stakeholders

In order to make the collected information readily available, easily retrievable, and clearly represented, we relied on an online interactive platform (Figure 1). In particular, we used the Smart City Logistics (SCL) platform (*http://iguess-sl.list.lu*), a Geographic Information System (GIS) developed by the Luxembourg Institute of Science and Technology (LIST) (Guerlain *et al.* 2016). In the platform, we replicated the same category/layer structure of Table 3.

The advantages of using such a platform are its user friendliness, its online access (i.e., the involved decision makers and relevant stakeholders can check the information and use the platform remotely) and its inter-operability between different systems. Indeed, the user can combine different layers via web services without IT expertise.

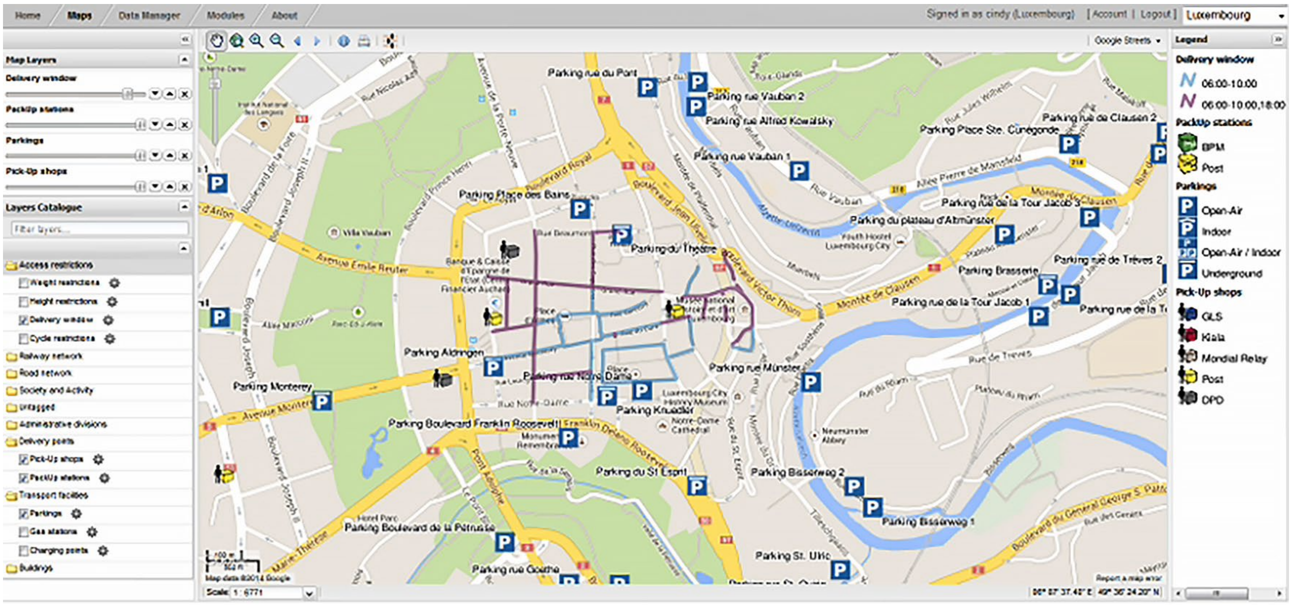

Figure 1. Screenshot from the Smart City Logistics platform (publicly accessible at: *http://iguess-sl.list.lu*)

2. Application cases of the framework: Bergamo and Luxembourg city

In this section, we illustrate the application of the framework and the SCL platform in two mid-size European cities: Bergamo (north of Italy, seat of the province of Bergamo) and the city of Luxembourg (capital of the Grand Duchy of Luxembourg). We demonstrate how the use of a common structure for describing and analyse UFT activities enables an easy comparison between cities. Moreover, we show how the use of the framework through the SCL platform in collaboration with relevant stakeholders can lead to the identification of different priorities of intervention for the two cities. In particular, we show how each layer can be integrated with the others in order to evaluate the applicability of a set of UFT solutions.

The two cities, sharing similar geographical, demographic and infrastructural characteristics (Table 4), have shown increasing interest for UFT issues, and have undergone a process of stakeholder involvement.

Both cities are set up in a hilly landscape: "*Città Alta*" ("upper city") and part of the "*Città Bassa*" ("lower city") in Bergamo and *Ville-haute* ("upper city") and *Grund* ("lower city") in Luxembourg city compose the historical part of the cities. Both cities are divided in neighbourhoods (7 for Bergamo and 24 for Luxembourg), with different characteristics. In particular, in both cities there are two quarters at the very centre of the city with the highest concentration of commercial activities and services. However, these neighbourhoods are also those with the highest historical relevance, thus more vulnerable to the negative impacts of UFT activities (e.g., noise, pollution, congestion).

The framework has been applied to the cities by two teams of researchers in the two cities between in 2015. One researcher joined both teams to ensure the consistency in the data collection.

After having collected the data and set-up the platform, several round tables and workshops organized with relevant stakeholders. In Bergamo, the key stakeholders involved were representatives of the municipal council of mobility and transportations, one representative of a large express courier, one representative of the local couriers, one technology provider and one representative of the shop keepers. In Luxembourg, the key stakeholders involved were the Ministry of Sustainable Development

Table 4. Some characteristics of the two case studies (reference year: 2014)

Characteristic	Bergamo (Italy)	Luxembourg
Morphology/area	39.6 km^2	51.73 km^2
Morphology/hills	Hilly landscape (min elevation: 211 m; max elevation: 645 m)	Hilly landscape (min elevation: 232 m; max elevation: 408 m)
Morphology/rivers, canals, waterways	No	Yes, but not navigable waters
Population/population	121316	107340
Population/population density	3063/km^2	2100/km^2
Historical heritage/old city	Yes (10% of the city area)	Yes (4% of city area)

and Infrastructure, representatives of the logistics service providers, one representative of the shop-owner association, own account transporters. The tool was used by the stakeholders to envision possible solutions for city logistics. The data collection process and the outcome of the use of the framework are reported in the next paragraphs.

2.1. Data collection

The framework provides directions about the potential sources of data and suggests how to classify the information. The collection phase (September 2014 – June 2015), however, remains an extremely time consuming activity aiming to reconstruct a comprehensive picture from sparse contributions.

Considering the two cities of Bergamo and Luxembourg, we relied on the maps provided by Google (*Google Terrain*) for the *morphology*, while municipality borders were gathered from OSM using postal codes. However, for the identification of neighbourhood areas and historically relevant areas we needed to access local documentation from the municipalities. Similarly, for the land use layer we needed to access to the municipalities development plan.

Data sources were different between the cities for what concerns *renting prices*: in Luxembourg, such information was available at the municipality level, while for Bergamo we relied on the data provided by one of the largest Italian online platforms for renting and selling houses.

Information about the location and typology of commercial activities required the use of distinct sources too. While for Luxembourg it was possible to rely on OSM data, for Bergamo there was a clear lack of data about the existing activities, which required to integrate the information with surveys carried out by the municipality.

We divided the *commercial activities* into different categories according to the nature and/or volume of the goods and related transport (Table 2). For Luxembourg, it was possible to use directly the OSM classification of activities. Thus, a furniture store was classified as dealing with bulky and non-food items, whereas a clothing shop was classified as dealing with small and non-food items. This classification allows the user to better identify potential customers of a logistics initiative. We did exclude supermarkets from the analysis as they have their own distribution systems in place.

Concerning *vehicles network, cycle network and pedestrian network*, we relied on OSM data that provided reliable information. For the bus lanes instead, we needed direct observations and data from the municipalities.

The information about *loading and unloading bays* in Bergamo was provided by the public administration while for Luxembourg City it was necessary to retrieve the information via direct inspection. Because of this, for both cities we focused only on a central area with a high density of commercial activities. Data about gas stations and electric vehicle charging station was retrieved from publicly available websites (e.g., *mylpg.eu*, *cngeurope.com*, *openchargemap.org*, *plugsurfing.com*).

Collecting information about the main *transportation companies* (express couriers and third party logistic companies) that regularly deliver the goods in the city, was very labour-intensive, as for Luxembourg the market turned out to be very fragmented, while for Bergamo some interviews were needed to understand which companies deliver in the city area.

Finally, neither city has specific *logistic infrastructures* in place, such as urban consolidation centres or city terminals, and no waterways were found.

In conclusion, although the data collection activity can hardly be standardized, the appreciation of the effort devoted to such activities in a real-scale case underlines the importance of having a proper method to organize the different layers of information.

Finally, the data gathered were uploaded on the SCL platform.

2.2. Results of the application of the framework and stakeholder engagement

The platform was well-received by the stakeholders that, after a quick demonstration, became able to directly interact with it. After a more general discussion about the characteristics and problems of the city, the researchers proposed to the stakeholders a set of UFT solutions to be analysed with the support of the platform.

For instance, Figure 2 shows an example of how the combination of the layers was used in the case of Bergamo in order to identify potential locations for an UDC. In the map in Figure 2 are visible the municipality/city borders, the historically relevant areas (*Città Alta*) and the quarters, which are all potential areas served by a UDC. The map also displays the shops that represent the delivery points and the motor vehicles network for the route calculation, location and accessibility of UDC and served area. Moreover, we can see the zones restricted to vehicles up to 3.5 tons.

From this map, it appeared that the historical centre (*Città Alta*) has a lot of shops, but a very low accessibility due to access restrictions and transport infrastructures. As a consequence, the stakeholders focused on this area to evaluate the possibility to develop a micro UDC for *Città Alta* in combination with electric vehicles and cargo bikes. Moreover, in Bergamo, the complex layout of the areas subject to restriction measures became clear to everyone after displaying the information using the SCL platform, while during previous meetings the representatives of transportation companies struggled to explain why this was a major issue for them.

As a result of the interaction with the stakeholders, we could identify the information layers that provide relevant information to the evaluation of different solutions (Table 5). It emerged that some layers are useful only for some solutions while others are more general. For instance, the localization of a freight terminal for modal shifts requires information on all types of infrastructure (water, air, ground transportation facilities) while the other solutions only need the road network.

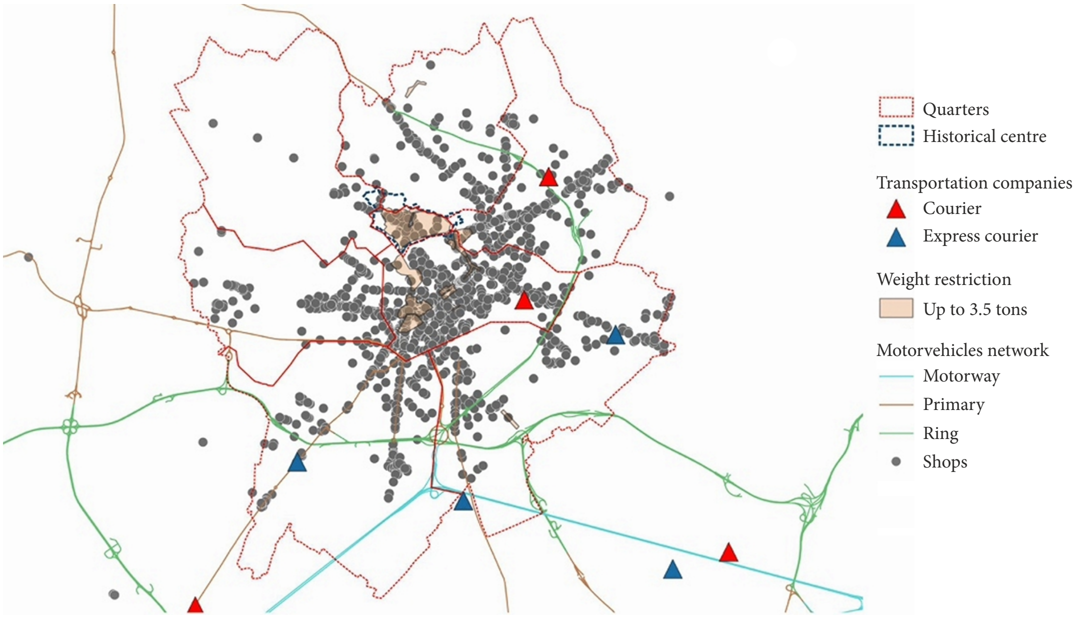

Figure 2. A selection of layers used to evaluate potential locations for a UDC (Bergamo)

It can be seen from Table 5 that the most used layers (at least for 4 out of 6 solutions) are:

- basic terrain map for spatial orientation;
- maps in the administrative units group: in order to identify the geographical limitations of the interventions (i.e., municipality/city borders or neighbourhood/quarters) or the critical areas to serve (i.e., historically relevant areas);
- population density and land use: in order to estimate the level and typology of the demand (for instance, distinguish high/low density residential/office/industrial areas);
- shops, for the same previous reason (estimate level and typology of demand);
- motor vehicles network;
- all the layers in the access restrictions group, to assess the current situation in terms of restricted areas;
- street parking and loading/unloading bays, since parking space near delivery points is necessary to implement almost every type of solution.

With reference to Table 3, all the information for the above-mentioned layers can be easily gathered, except for loading/unloading bays and access restrictions that need to be retrieved from the municipality. However, from the combination of Table 3 and Table 5, future users of this framework can decide whether gather information for all the solutions or focus on one specific solution and gather only the information that is needed. From our experience, we suggest gathering as much information as possible since there are a lot of communalities and synergies in the data gathering process.

After the evaluation of the different solutions, these were prioritized by the stakeholders.

The existence of an historic centre and the hilly morphology emerged as two very relevant factors for both cities. In fact, to preserve historical centres, policy makers define areas with specific delivery windows and the hilly landscapes further limit the accessibility to delivery vehicles. While restrictions can be good in principle, in practice, they often bring to a fragmentation of the deliveries. This problem is particularly evident in Bergamo, where the areas subject to restrictions are many, discontinuous in space and not homogeneous in time. However, also in Luxembourg there are different delivery windows in the streets in the same area, thus leading to potential confusion for transportation companies not accustomed to. These considerations led the stakeholders in both cities to agree on a harmonization of such measures.

In terms of transportation infrastructures, the two cities appear quite similar, but significant differences emerge in terms of typologies of shops: Bergamo has a relevant share of shops in the "commerce small items" category and Luxembourg in the HORECA (food service industry) one. This observation led to the possibility to experiment electric vehicles distribution in Bergamo. Moreover, Luxembourg features a very fragmented market of the transportation companies, thus suggesting the need of a consolidation centre. On the contrary, in Bergamo, where there are already few companies operating, therefore a micro urban consolidation centre could be designed for the parts of the city more difficult to reach and with higher historical value (i.e., *Città Alta*).

Furthermore, in Bergamo there seems to be a mismatch between the location of loading and unloading bays and the shops while in Luxembourg the issue concerns the narrow time window exclusively dedicated to deliveries operations. As a consequence, in both cities emerged the need to review the loading/unloading bays layout and policies.

Table 5. Combined use of layers to support solutions evaluation and design

Group	Layer	Freight consolidation and delivery by truck (CC – Consolidation Centre)	Modal shift (only localization of the freight terminal)	Access restrictions, charging and environmental standards	Lane and space use	Alternative fuels/vehicles	B2C solutions
Morphology		Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation	Basic map for spatial orientation
Administrative units	Municipality/city borders	Limit of the area served by the CC		Limit of the authority for restriction	Limit of the authority for regulation	Limit of the authority for incentives	
	Historically relevant areas	Potential area to serve from the CC		Potential area to restrict access	Localization of loading bays	Potential area to serve	Identification of served areas
	Neighbourhood/quarters						
Society and activity	Population density	Localization and potential area to serve from the CC	Localization of the freight terminal (avoid dense/residential areas)	Type of intervention (e.g. noise reduction in dense/residential areas)	Demand estimation	Potential area to serve	Demand estimation/ categorization
	Land use						
	Rent prices	Localization of the CC (space cost)	Localization of the freight terminal (space cost)				
	Shops	Demand estimation, delivery points		Balance restrictions with shop owners' needs	Demand estimation, localization of loading/unloading bays	Demand estimation, delivery points	Potential pick up shops
Road network	Motor vehicles network	Route calculation, location, accessibility of CC and served area	Localization of the freight terminal	Define restrictions at the street level		Route calculation; Network, which can be used	Accessibility of delivery points
	Cycle network						
	Pedestrian network						
	Bus lanes	Reserve lanes for CC vehicles			Lanes, which can be used for delivery vehicles	Reserve lanes for electric vehicles	
	Traffic flows	Critical areas, location of the CC		Potential area to restrict access			
	Pollution levels					Potential area to serve	

End of Table 5

Group	Layer	Freight consolidation and delivery by truck (CC – Consolidation Centre)	Modal shift (only localization of the freight terminal)	Access restrictions, charging and environmental standards	Lane and space use	Alternative fuels/vehicles	B2C solutions
Access restrictions	Access restrictions (height/weight/width)	Identify constraints for the CC vehicles		Evaluate/harmonize existing measures	Identify constraints to reach loading/ unloading bays; Current restrictions	Potential area to serve; Evaluate existing measures; Incentive for alternative/clean vehicles	Identify constraints to reach delivery points
	Road barriers			Evaluate/harmonize existing measures, Current restrictions	Identify constraints to reach loading/ unloading bays		
	Limited traffic zones					Potential area to serve; Potential incentive for alternative/clean vehicles	
	Delivery windows						
Transporta-tion facilities	Airports	Localization of the CC	Localization of the freight terminal				
	Water network						
	Charging points					Route calculation; Service offered to logistics providers	
	Alternative fuels stations						
	Street parking	Identify parking points for CC vehicles		Parking areas affected by restrictions	Identify available spaces, evaluate current situation	Identify parking points for vehicles, Potential incentive for alternative/clean vehicles	Identify parking points to reach delivery points
	Loading/Unloading bays						
	Parking lots	Identify hub areas, facility, which can be used		Accessibility	Use parking lots as hub areas		
Delivery points	Parcel solutions						Evaluate existing solutions; Service offered to consumers
	Transportation companies/couriers	Potential suppliers	Potential partner		Potential user		
	Logistic infrastructures (UCD, city terminals)	Evaluate existing solutions, facility, which can be used	Evaluate existing solutions				Facility, which can be used
Railway network	Railway network	Localization of the CC	Localization of the freight terminal				
	Tram network						

For the future developments, each solution will be evaluated in detail by the research teams in collaboration with the stakeholders. For brevity sake, we do not enter in the detail of how these solutions were identified and prioritized, as our focus in this paper is on the framework that enabled such outcomes.

Conclusions

A better understanding of the city's context and stakeholder engagement are essential to propose adequate solutions in the field of UFT. However, collecting and sharing information with decision makers is a complex and time consuming task.

The framework presented in this paper allows the identification and evaluation of the most important dimensions affecting UFT, designed with the specific objective to enable stakeholder engagement and solution identification. The framework also supports the comparison between cities to foster the discussion and the UFT solutions to benchmark.

The framework is designed to exploit as much as possible open data, such as OSM data for infrastructures and commercial activities. The organization of the data and information in layers supports the understanding, analysis and discussion between stakeholders.

To show its use, the framework was applied on two cities (Bergamo and Luxembourg). The cases helped to assess the quality and reliability of the information retrieved and demonstrated the ability of the framework to identify and make comparable the different features of a city. Moreover, the cases proofed that a visual tool derived from the framework can be of great help to engage stakeholders in the early phases of the design of UFT solutions. Finally, the cases helped to understand which data from the framework can be more helpful in the analysis of specific UFT solutions, hence providing a practical example for future users.

In conclusion, building up on previous literature and case studies, this paper provides a standard framework for supporting the data collection, comparison and stakeholder engagement. Because of this, our work can be particularly useful for both researchers and decision makers working in cities still at the beginning of their city logistic journey. However, even more advanced cities could benefit from our insights in order to enrich their data sources and benchmark against other cities.

Our framework is subject to several limitations that we plan to overcome by including an analysis of the traffic, provide a set of quantitative indicators for the different features, enrich the list of features, and develop demand estimation models based on the collected information. Moreover, we purposefully excluded large retailers and supermarkets that have their own distribution systems in place. However, they are an important part of the picture when considering the demand, traffic and interactions with the other solutions. For instance, some retailers can host parcel lockers in their stores or parking lots. Because of this, we envision our framework as a platform, open to future technological advancements (e.g., new available data sources, new solutions) and new case studies so to have a growing library of shared experiences. Finally, the framework should be tested on additional cities, from small to large sized cities and with additional features such as construction logistics to validate its robustness and complete the list of city's characteristics and potential sources.

Contribution

All the authors contributed equally to the development and writing of the paper.

Disclosure statement

Authors declare they have no competing financial, professional, or personal interests from other parties.

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