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Freight distribution in urban areas: a method to select the most important loading and unloading areas and a survey tool to investigate related demand patterns

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Abstract

Cities all around the world are observing increasing levels of urban freight activities owing to the growth of internet shopping combined to the traditional distribution to shops, creating additional problems in terms of congestions and environmental impacts. This study, developed within the European Project SUITS framework, aims at showing how Local Authorities can effectively observe freight flows from the demand side. This led to the design, implementation and testing of a spatial cluster analysis approach to understand which are the most important loading/unloading parking spots in an urban setting by processing the GPS traces of a fleet of logistic vehicles. Later field activities should focus on these important areas to maximize the efficiency of the survey. A survey of retailers and shops in such areas to observe delivering activities is then proposed. The whole process, namely the spatial analysis and the field survey, was then tested to the real case of an Italian city (Turin) to assess the potentiality of the methods. The methodology proposed can give useful insights to Local Authorities on a way of monitoring the freight distribution patterns at the more disaggregated individual loading/unloading area.

Keywords: Freight distribution, Urban mobility, GPS traces, Cluster analysis, Spatial clustering, DBSCAN

1 Introduction

In cities usually affected by critical traffic conditions, high levels of urban freight activities may create additional problems in terms of congestion and environmental impacts [1]. In recent years, an increasing amount of goods is observed travelling around to be delivered directly to individual consumers, instead of arriving in bulk to selected store locations [2]. Moreover, retailers and shops themselves are leaning more and more on express couriers for the deliveries of the goods they are selling, mainly in the city center because of the reduced stocking spaces characterizing their locations. As a consequence, a larger number of vehicles travelling around for such deliveries purposes sums to the already rather great amount of traffic affecting congested road network. Local Authorities (LAs), which are responsible for city mobility and quality of life, plays a fundamental role in facing these issues: this requires urban freight transport being part of a city strategic management [3]. However, "the number of different definitions of urban freight transport and city logistics reflects the complexity of this field and the persistent lack of consensus on how to address the issues" ([4], page 2). Moreover, the urban freight transport planning process involves various aspects, as the monitoring of the freight activity, the understanding of the local supply chains, and the stakeholders' involvement. As observed in [3], there are three main facets when dealing with urban freight transport, namely the demand of goods and services, their delivery and the physical environment, regulated by local

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government services. All these preliminary points highlight the variety of aspects that worth to be treated while dealing with this topic.

The point of view we would like to consider is the Local Authority's. It is as a key figure that is expected to take into account the needs of different stakeholders involved in the field while developing a proper strategy for urban freight transport, through the collaboration with all the actors involved. Looking at the European level, the European Commission requires cities to define urban freight plans in order to study measures to deal with the efficiency of urban logistics, with the challenging objective of reducing the related externalities of greenhouse gas emissions and noise [5]. The policy measures proposed to improve sustainability at the city level can commonly belong to three kinds: pricing initiatives, licensing and regulation efforts, and parking and unloading initiatives [6]. Many urban authorities have been asked to focus on the efficiency and sustainability of freight transport due to its economic importance over the last decade. Sustainable Urban Mobility Plans (SUMPs) are the key tool for European LAs in the planning, development and implementation of adequate transportation management. These plans consider the main features of sustainable transport and have to devote specific actions in their logistic components in the so-called Sustainable Urban Logistics Plan – SULP [3]. However, Local Authorities capabilities in planning freight movements are often limited, at least compared to the attention paid to passenger transport issues.

Acknowledging such gap, the EU CIVITAS initiative (https://civitas.org) has taken many actions to help cities in implementing measures to improve freight movement and reduce the related negative impacts [4]. Within CIVITAS, the SUITS project (Supporting Urban Integrated Transport Systems: Transferable tools for authorities - http://www.suits-project.eu/) focuses, among other things, on integrating urban mobility planning practices of both freight and passengers and on showcasing how the joint exploitation of mobility-related data that are seldom jointly considered can lead to new knowledge and better insights on the transport system of an urban area, thus contributing to the definition of more efficient and effective policy measures. Nine cities are members of the SUITS consortium, namely Alba Iulia (Romania), Coventry (UK), Erfurt (Germany), Kalamaria (Greece), Palanga (Lithuania), Rome (Italy), Stuttgart (Germany), Turin (Italy) and Valencia (Spain). Evaluations conducted during the earlier phases of the project revealed that many of these cities need, in fact, support in the implementation of measures related to freight distribution and data analyses [7].

The importance of data collection as a step for the analysis and the observation of freight movements at the city level is a priority of the H2020 Research Programme [8]. However an absence of proper focus on data collection and modelling was observed, despite these are essential stages in the planning and implementation of solutions based on the real needs of operators and LAs [8], even if different approaches have been proposed in the literature. For instance, Nuzzolo et al. [2] investigate the characteristics of freight demand in three different European cities (Rome, Barcelona and Santander) combining traffic counts of vehicles and interviews with randomly selected retailers and truck drivers. The final aim is to collect insights into the characteristics of commodity flows per freight types, shipment size for freight and transport service types. An establishment-based freight survey is studied in [9], demonstrating that it can provide worthy information and data on urban freight flows and operations. At the same time, this kind of investigation is usually characterized by a high investment request, a strict correlation to the recall of respondents and a low insight on vehicle activity [10]. As discussed in [11], urban freight data are essential to managing such travel demand appropriately.

Once assessed the important role played by data in the observation of urban freight transport, it is necessary to focus on the approaches available for their collection. On the whole, a variety of survey techniques has been commonly used in the last 50 years to deepen this knowledge, as reviewed by Allen et al. [10]. Although traditional surveys are the most popular methods, some limits arise and ensuring the quality of data implies an increasing cost both in time and money [12]. In the meanwhile, the possibility of collecting detailed travel information has broadened thanks to developments in Global Positioning System (GPS) technology. In fact, the integration with Geographic Information Systems (GIS) allows to easily determine origins, destinations, travel times, distances, routes and vehicle speeds at highly disaggregate levels of spatial and temporal resolution [13]. At the same time, GPS can also be used to record stops for loading, unloading and parking [10]. The updated guidelines also recommend the collection of this kind of data for developing and implementing a SULP [11]. Obviously, as suggested in the cited document, it is crucial to cooperate with stakeholder and data owners trying to establish long-term agreements to ensure proper data supply. The collection of freight-related movements information can be too costly for LAs, given their budgetary priorities. So, Municipalities are expected to reach some good agreements with operators owing data proposing, for example, the disclosure of such datasets against area access permission and operational licenses for the activities that constitute main freight transport generators [11].

The general conclusion from the above short review and discussion is that LAs are more and more acknowledging the importance of proper management of urban freight movements, but are not enough focusing on related data issues nor exploiting the opportunities related to passive data collection streams such as GPS traces. The present study would like to fill some of the knowledge missing at that level, since it focuses on the development of a methodology that can help cities to investigate a specific aspect characterizing and influencing their mobility, namely the observation of freight deliveries from the demand side, i.e. through the observation of the delivery points in urban areas.

This is hopefully achieved by proposing an innovative approach that exploits GPS traces, firstly, to analyze the places where a fleet of logistics vehicles is delivering or picking up parcels. This dataset is then studied to identify which of these places are more relevant for the fleet operations and therefore deserve additional investigation. Criteria to select such places based on both GPS traces and additional considerations are discussed in the paper. Indeed, such selection needs to be carefully done in order to concentrate the survey efforts and maximize efficiency. Finally, a vehicle observation survey is designed to understand in-depth the demand for freight transport in the selected loading and unloading areas, which requires the presence on the field of technical staff and that, therefore, could not be spread to all service points of a city. The method to select a set of loading/unloading points was applied on a dataset from real operations in the city of Turin (Italy). In the final phase of the research the survey instrument was tested into one of those points.

2 Methods

The next sections will present the main steps of a methodology developed to help municipalities to gain a better knowledge of freight distribution patterns at the more disaggregated individual loading/unloading area through the exploitation of logistics vehicles GPS traces.

The proposed approach starts from the identification of the locations where vehicles commonly stand for their deliveries. Then, a specific clustering algorithm is applied to identify the zones with the largest number of stops, which is one of the selection criteria to identify the most important areas. The subsequent step integrates the outcome of the algorithm by introducing four aspects related to typical characteristics of the loading/unloading spots and of the delivering means. Such criteria along with the results of the clustering algorithm are used to select a reduced number of areas (possibly only one) where it is interesting to investigate the parcel distribution in more detail. Finally, a specific survey is proposed to collect information on freight patterns from the demand side by focusing on retailers and shops in the above-selected area. Data derived can help to understand the current exploitation of the loading/unloading spots and the freights flow from the demand side. The following subsections illustrate the above method more in details.

2.1 Identification of vehicles stops

The first step in our approach requires the analysis of vehicles travelling around the city to identify the locations of their deliveries. A possible way of achieving it is through the analysis of GPS traces, a kind of data commonly exploited to track the vehicles at the urban level or on long distances [12, 14–17].

On the whole, not so many papers deal with the analysis of stops that can be inferred from this kind of recordings. Different approaches within such research domain are proposed for freights travelling on long distances or for those moving in the urban context. Examples belonging to the former case are those of Aziz et al., who try to identify the functionality of truck stops on highways from GPS data [18], and of Haque et al., who aim at predicting truck parking utilization at rest areas for parking management reasons [19]. At the city level, instead, the evaluation of vehicles stops could be useful to classify them according to their purpose (work or non-work related) [20], for the optimization of the urban freight transportation system [21], for evaluating delivery performances (e.g. speeds, travel times, delivery times) and fuel consumption and emissions [22] or for the computation of practical indicators helping LAs to gain insights into the urban transport activities [23]. In the current work, GPS traces are instead analyzed to derive two pieces of information: 1) the time that each vehicle loses in congestion in each street that it travels through and 2) the identification of the stops that are made to pick up and deliver goods. The former analysis is not reported here but it is presented in [24]: we directly make use of related results in the following.

Concerning the latter point, we preliminarily notice that a vehicle might not move due to different reasons, including making deliveries but also stopping at crossings to give way, at a red light or due to congestion. Hence, it is necessary to distinguish service stops from stops due to traffic conditions. Following the approach proposed in [24], stops whose duration is shorter than 120 s (2 min) are considered as due to traffic conditions, because this is a typical maximum duration of a stop caused by the red phase of a traffic light or for yielding. Service stops are, instead, supposed to be normally longer than this threshold, as suggested in previous research [13]. The selected value is assumed in fact as a good compromise for the proper identification of service stops, bearing in mind the existence of deliveries that could be managed in less than 120 s and the possibility of being stuck in traffic for more than 2 min.

2.2 Selection of a subset of stops through spatial clustering

The next step in the methodology requires the identification of clusters of points among those available: in such way, it is then possible to focus on the most important sites where the tracked vehicles usually stop in order to implement the survey. In fact, it is clearly not feasible to organize a field activity covering the whole area, whereas on the other hand many stops are often concentrated in given places. On the other hand, vehicles are not always stopping at pre-defined locations but in practice they usually stop all along the buzziest streets to minimize distances that need to be covered on foot. It is therefore difficult to decide exactly where to go to administer the survey. A spatial analysis of these stops positions is needed to find in which points one should concentrate the field activity to maximize its efficiency. Cluster analysis can help in this case, since it is a technique aiming at finding collections of objects such that the elements in a group will be similar (or related) to one another and different from (or unrelated to) the elements in other groups [25]. Examples of exploitation of this data mining methodology can be found in different domains of transport engineering such as transit quality evaluation [26] or tours classification [27], while its use in urban logistics can be exploited for the organization of deliveries according to city's characteristics [28] or the optimization of freight transport system's performances [29].

Different clustering techniques are available according to the kind of dataset that has to be analyzed. Since we are working with geolocations, a suitable method is to consider a density-based algorithm [30]. In this case, a cluster is a dense region of points, which is separated from other regions of high density by low-density areas. The method is usually applied when clusters are irregular or intertwined, and when noise and outliers are present [25]. In the current methodology, the application of such procedure could help to remove the noise, i.e. the areas where a low number of stops are found, and to focus on the most important ones. This approach is similar to the one proposed by Aziz et al. in [18], but in the present work the target is a different kind of vehicles (vans rather than trucks) and a different context (urban level rather than highways).

DBSCAN (Density-based spatial clustering of applications with noise) is a density-based algorithm where density represents the number of points within a specified radius (*Eps*) and a point is a core point if it has more than a specified number of points (*MinPts*) within *Eps*, so that these are points that are at the interior of a cluster. A border point has fewer than *MinPts* within *Eps*, but it is in the neighborhood of a core point. Finally, a noise point is any point that is neither a core point nor a border point [25]. The approach used to identify the cluster of stop positions is based on the following computational steps:

1. Consider the positions (latitude and longitude) of all the stops
2. Min-Max normalize to have uniform maximum and minimum values [0–1]
3. Apply the DBSCAN algorithm to the dataset, with *Eps* = 0.005 and *MinPts* = 5

The latter two parameters have been selected to reach a good compromise between the minimum number of elements needed to create a cluster (*MinPts*) that corresponds to the number of delivery stops found in a certain site, and the distance (*Eps*) that could be approximately assumed to be equal to 8 m.

The application of the clustering algorithm allows to classify a certain number of stops positions as noise, i.e. not assigned to a cluster, meaning that they are located in sites not so commonly used for deliveries. At the same time, the remaining elements define some clusters that have to be investigated in more details to identify a restricted set of clusters that contain a considerable number of stops. A possible threshold could be set to one delivery for each working day.

2.3 Additional selection criteria of the areas where the survey should be run

The procedure presented so far produces a restricted number of locations where a loading/unloading survey can be implemented. However, additional selection criteria for clusters can be evaluated, beyond the above-considered minimum threshold in terms of the number of service stops, in case the number of clusters is still too high. With this aim, four additional qualitative and quantitative aspects that could be relevant in different policy-making contexts are introduced and discussed in the following. All these are based on the expertise and feedback obtained from SUITS partners, namely city representatives on the one hand and researchers on the other. These aspects and the related criteria to assign ratings in terms of low, medium or high priority in selecting an area to implement the field activity are as follows:

- First aspect: the number of vehicles delivering in a specific cluster, irrespective of the number of service stops. This could correspond to a more frequently used location that could provide interesting and useful information during the survey data collection. The mode of the distribution of the number of vans stopping in an area is taken as a threshold and it corresponds to a medium rating of the priority for the roll-out of the survey, while higher numbers of vans identify areas with higher priority and lower numbers the opposite.

- Second aspect: congestion issues. The productivity of vehicles, which can be directly measured through the mean commercial speed of the tour, is differently affected by congestion according to the specific tour. By computing the key performance indicator related to congestion presented in [24], the focus goes on vehicles that wasted more time because of congestion and that realized at least one service stop within any of the obtained clusters: we then consider the number of stops they make and areas less frequently visited by these vehicles receive a low rating, whereas areas with a higher number of such stops have a medium or high rating. It is then possible to understand which of the clusters is more related to vehicles that have relatively lower productivity, and for which it is therefore more important to take some corrective action.
- Third aspect: street characteristics, such as access restrictions. Areas situated within roads with restricted access are less likely to be affected by traffic flows and are therefore not considered as priority areas for further investigation, earning low ratings: examples are pedestrianized streets where access is allowed to permit holders, as commonly happens for logistics operators. Sometimes, these permits include the possibility of travelling also along roads that can only be accessed by public transport in specific time ranges: a medium rating is assigned in these cases. Finally, high ratings are associated with areas where the logistics vehicles are commonly sharing the space with ordinary traffic flows for the majority of the time during the working days.
- Fourth aspect: location of retail outlets. This kind of dataset provides information on where the vans need to stop for their deliveries. In fact, many shops are nowadays supplied through parcels rather than bulk shipments with trucks, especially in the city center where the dimensions of the shops themselves are smaller and they do not have enough space for large stocks. To consider such aspect, high ratings are given to areas with a higher number of commercial activities in their proximity. Information is accessible thanks to specific maps commonly made available by municipalities, or can be found on web mapping services.

The above criteria are used for a comparative analysis of all the areas selected by the clustering algorithm, with the final goal of selecting a furtherly reduced number of zones where to run the survey.

2.4 Description of the on-site survey

The final step in the proposed approach includes the implementation of a survey aimed at collecting information on freight flows from the demand side by focusing on retailers and shops in the above-selected area(s). Within a specific observation period, all stop events are recorded. A *stop event* is specified as any vehicle (including trucks, vans and cargo bikes) stopping within the boundaries of the area and from which parcels are either unloaded or loaded, irrespective of the fact that such parcels will either go inside or outside such area once having left the vehicle or come from a location outside or inside the area before getting on the vehicle. Within each stop event, more than one *deliveries* or *pickups episodes* could take place, according to the number of final destinations and origins of the parcels. The surveyor separately records all these deliveries and pickups. For example, during a stop event the operator could take two parcels out of the vehicle at once, and drop them at two different locations, while collecting a third parcel from the second location that is finally loaded on the vehicle. These three different episodes within the same event are then separately recorded. On the other hand, bulky deliveries might require more than one trip from the vehicle to the final destination, and in this case only a single delivery episode is recorded.

The following information is recorded for each stop event:

- Operator
- Kind of vehicle: make & model
- Fuel
- Plate number
- Exact stop location
- Initial time of stop
- Final time of stop,

whereas the following information is recorded for each pickup and delivery episode within each stop:

- Number of packs delivered or collected
- Approximated linear dimensions or volume
- Means of delivery or collection (e.g. by hand, trolley, pallet)
- Exact location of the destination of delivery or origin of pickup.

The collected information can be further analyzed according to the specific needs of the Local Authorities. However, it is anticipated that the focus of this paper is not to discuss a specific use of the data gathered through the above survey, but rather to test both the loading area selection process and the functionality of the survey instrument in a real case study. Here it is only noted that useful insights into the delivering operations can be achieved, both in terms of mode used (vehicles and final means of delivery/collection) and in the timing of different loading and unloading operations while the vehicle is stopping. It is also possible to better know the exact place where vehicles stop: the aim is to check if load/unload areas are properly exploited.

3 Case study and results

3.1 Test field and datasets

The method introduced in the previous section was tested on a real case study in Turin, a city of about 883,000 inhabitants located in the north-western part of Italy and surrounded by a metropolitan area of about 2 millions inhabitants. Like most of the largest urban areas, the central area is a "Limited Traffic Zone" (LTZ), having a size of about 2 * 1.5 km. The LTZ contains a large proportion of mobility attractors, including shops, business districts and public offices, and has a car access restricted during the morning peak hour.

Both the Turin municipality and its in-house company 5 T, which manages the traffic control system and other mobility services in the city and beyond, are partners of SUITS project and provided the data that were used in the present research. This dataset includes the traces, i.e. GPS locations, of a fleet of 28 logistic vehicles serving the central area of the city in a whole month period (May 2017). These recordings are available thanks to a special agreement between the City Council and the haulage companies. According to such agreement, companies' vehicles have an easier access inside the LTZ against the disclosure of such GPS traces. Although the size of the sample seems quite small compared to traffic flows in the city, it should be mentioned that these tracked vehicles represent approximated 1/3 of all vehicles that enter the LTZ and that they were monitored for a quite long period. Therefore this sample can be considered as representative of the operation of vehicles in that area.

The dataset contains the following information: vehicle ID, timestamp, the validity of the measure of the position (yes/no), latitude and longitude which are recorded every 10 s, instantaneous speed and direction (course). On the whole, a total number of 360,820 positions for the 28 different vehicles registered in the month of May 2017 is available. Our analysis will focus on a specific area of the city, namely the above mentioned Limited Traffic Zone, and on weekdays (Monday to Friday, excluding holidays) within the observation period.

3.2 Identification of the vehicle stops

The first step was to process the previously introduced dataset to gain information on the locations of stops. This analysis requires to compute the overall time interval for a series of subsequent 0 speed recordings: if it is larger than 2 min, a service stop is identified and its location is reported as the average of all those positions. Three thousand three hundred thirty-six stops were found and linked to the vehicles delivering in the selected area, with the original fleet size reducing from 28 to 19 since the remained did not deliver in the LTZ.

The locations of stops are represented in Fig. 1, where each color represents a different vehicle. This picture can already provide some insights into the delivering patterns in the city center. For example, it is interesting to note different vehicles serving different parts of the LTZ, while they seem to make more or less the same tour day after day. Moreover, a visual inspection allows finding some spots where a lot of points overlap or aggregate, whereas other stops seem to be more isolated. A simple look at this figure clearly shows the need for a loading areas selection procedure to identify a manageable number of areas where it is convenient to concentrate surveying activities.

On the whole, this dataset can provide some further preliminary information. The service stops were done in 20 different weekdays of May 2017, mainly in the time range 8 am-7 pm. Moreover, it is possible to check the number of stops done in a month by all the vehicles delivering in the LTZ (Fig. 2). Large differences are observed, quantitatively confirming the visual results observed in Fig. 1. More in details, Fig. 3a shows that most of the deliveries are done from 10 am to 4 pm. This information can also be exploited for a proper organization of the on-site surveys, namely selecting a time range that could be characterized by a considerable number of delivering operations to be investigated. Further preliminary analysis can focus on the duration of stops (see Fig. 3b), which should be considered in designing the survey so that it does not take too long to gather all data. The large majority of vehicles seems to manage the delivery operations in less than 10 min, with the highest frequency of stops durations being included in the 2–5 min range.

3.3 Selection of a subset of stops through spatial clustering

Once some knowledge has been gained on the dataset collecting the 3336 stops locations found in the Turin LTZ, it is possible to apply the subsequent step of the methodology proposed. DBSCAN algorithm is, in fact, implemented and used to analyze the dataset through a free and open-source data analytics, reporting and integration platform named KNIME, which integrates various components for machine learning and data mining [31]. After the application of the clustering algorithm, 1825 items among the 3336 positions are classified as noise (55% of stops), i.e. not linked to a cluster, meaning

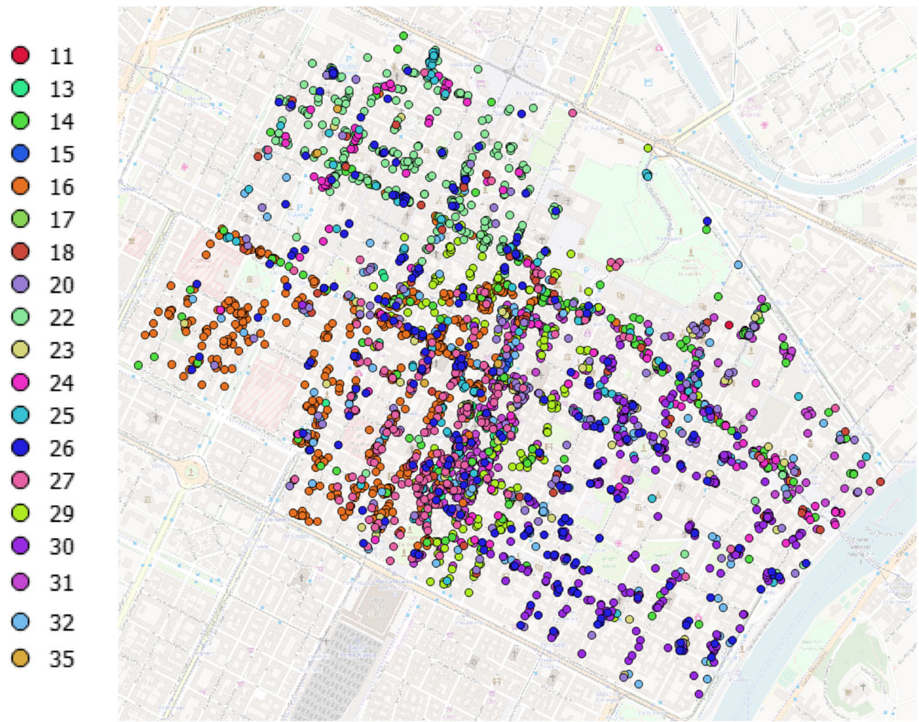

Fig. 1 Service stops of freight distribution vehicles in the Turin LTZ, May 2017: each color represents a different vehicle (vehicles IDs available on the left)

that they are located in sites not so commonly used for deliveries. At the same time, 140 clusters are defined from the remaining 1511 elements. In order to focus on clusters representing more intense activity, we consider a set of 41 clusters out of 140 that contain at least 10 stops, and then we narrow down such sample to another set of nine clusters that contain at least 20 stops. This latter set is made of 376 service stops, i.e. more than 11% of the total, and thus represents a reasonable sample. Both sets are in the following Fig. 4, where the locations of the designated loading/unloading areas are also represented. This latter dataset was provided by the Municipality of Turin and consists in a GIS layer that collects all the 250 load/unload parking spots which are available within the LTZ. The superimposition of the information deriving from the two datasets could inform on the frequency of use of the available load/unload areas. However, a detailed investigation, as the one available through an on-site survey, is required to better understand which could be the causes of low exploitation of those parking spots.

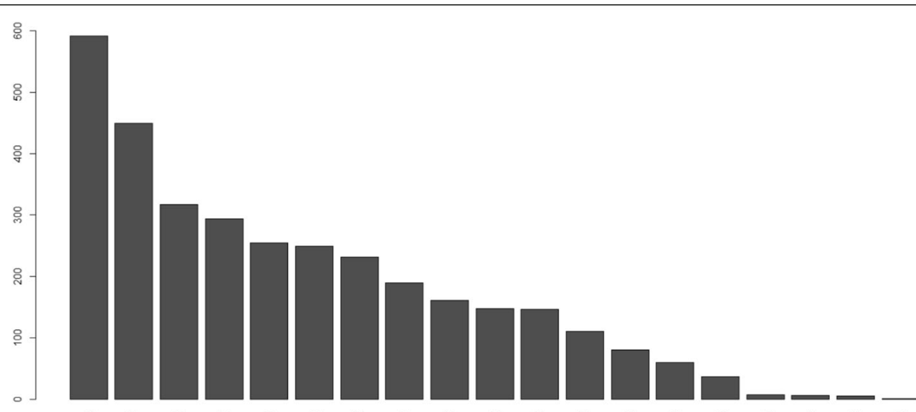

Fig. 2 Number of service stops for each vehicle in May 2017 (vehicle IDs on the x-axis)

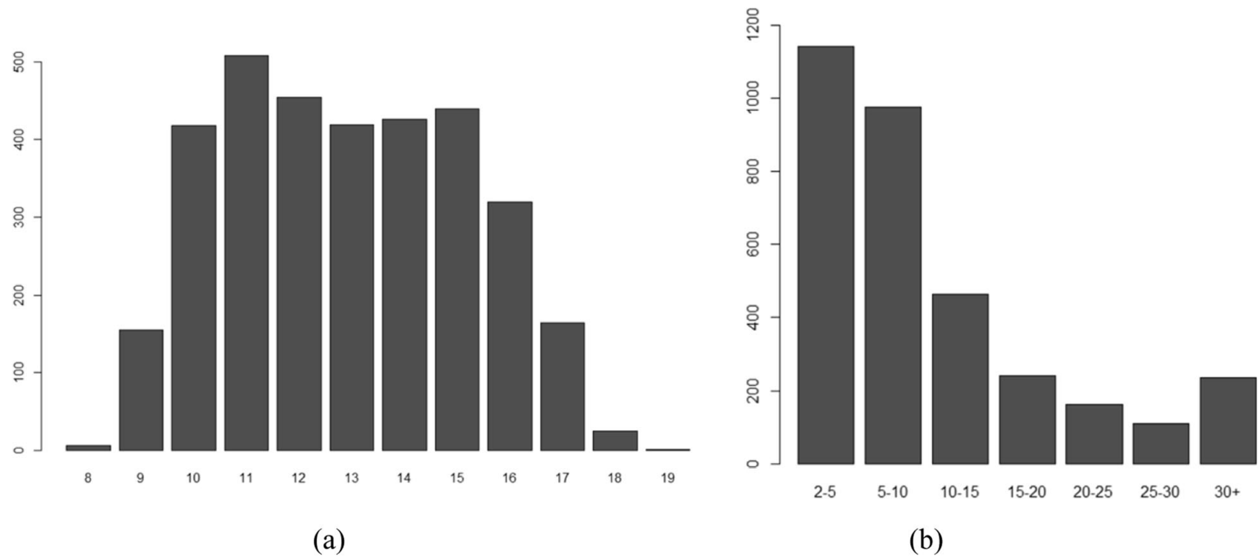

Fig. 3 Distribution of the stop time between 8 am and 7 pm (**a**) and of the stop durations in minutes (**b**)

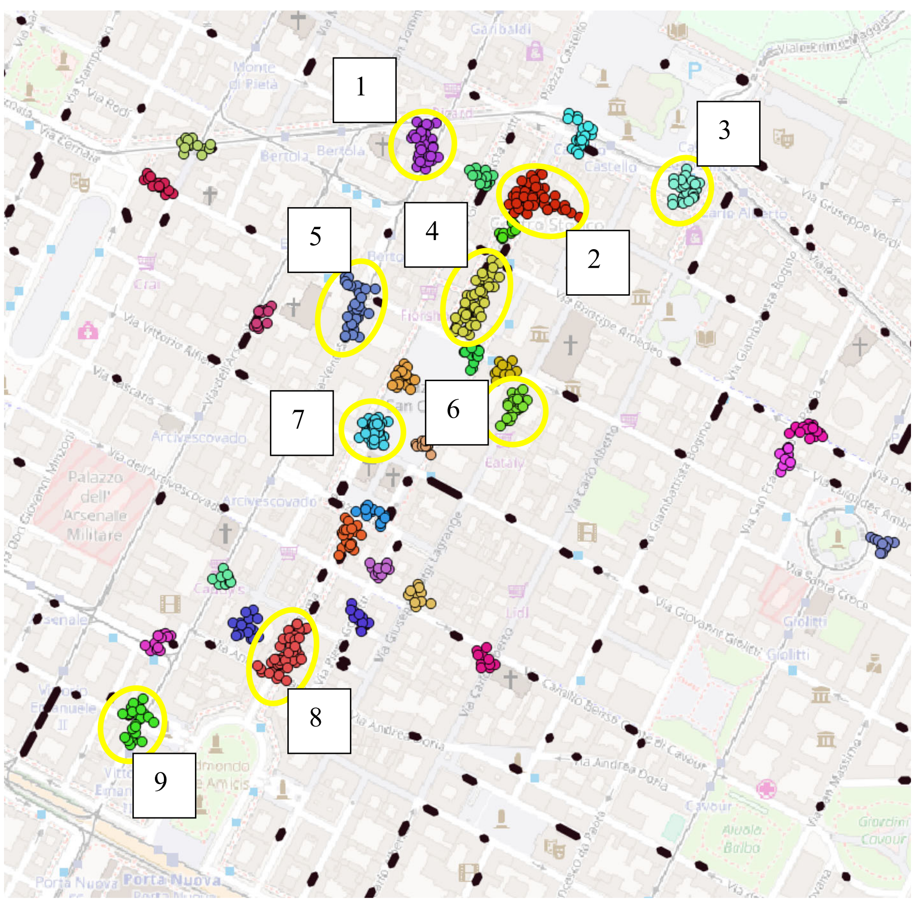

Fig. 4 Clusters with at least 10 stops (colored dots), clusters with at least 20 stops (yellow ovals) and designated load/unload areas (black signs)

3.4 Final selection of a stop where to run the survey

The nine areas obtained from the previous steps of the methodology could represent a manageable number of spots where a loading/unloading survey can be implemented. However, for illustrative purposes we apply the four additional criteria defined in section 2.3 through a comparative analysis of those areas, with the final goal of selecting one zone where to conduct the survey. Table 1 reports the results of the evaluation exercise on the nine zones: each line collects the entity of the priority for the survey roll-out, each column refers instead to one of the four aspects. The ratings displayed in the table were discussed among experts in the SUITS consortium that have a knowledge of both the concept under investigation and of the study area.

The second column labelled as "Number of vehicles" deals with to the first of the four criteria described in section 2.3: the mode of the distribution is equal to 8 in the current case and the priority ratings are assigned consequently.

The evaluation of the congestion issues is related to the ratings of the third column of Table 1. The computation of the key performance indicator [24] allows identifying the vehicles that wasted more time because of congestion and that visited at least one service stop within any of the nine clusters. Three vehicles out of the 17 delivering in these areas were selected: the number of stops they make is then considered and we give a low rating to areas less frequently visited by these three vehicles, whereas areas with a higher number of such stops have a medium or high priority rating.

Some detailed knowledge of street characteristics has to be collected to assign ratings reported in the fourth column in Table 1. In Turin, the access to the LTZ is restricted to the vehicles with special permission from 7.30 am to 10.30 am during a working day: we assign a high priority rating to areas that are located here, being the ones more influenced by ordinary traffic flows (Area 3 and 8). Many streets, instead, can only be accessed by public transport from 7 am to 8 pm, whereas others are pedestrianized: in both cases, access is possible only to permit holders, as logistic vehicles can commonly be. On the whole, areas situated within roads with restricted access are less likely to interfere with traffic flows and were therefore classified with a low or medium priority rating depending if they are located in pedestrian streets (i.e. with reduced amount of traffic) or along roads with public transport means travelling.

Finally, we evaluate the fourth criterion (last column of Table 1) thanks to the open GIS data web site of the Municipality of Turin (http://geoportale.comune.torino.it/web/), where it is possible to access a map which contains all the locations of commercial activities of the city. In this case, we give high ratings to areas with a higher number of commercial activities in their proximity.

Based on the qualitative and quantitative evaluation results provided in Table 1, the selected area where the load/unload survey is run is the number 8 which is located in via Roma, between the crossings with via Gramsci and via Buozzi (see the map of Fig. 4). This area is characterized by the largest number of vans delivering to it, who suffered from most delays. It also has a high density of retail outlets and express couriers' drivers have to deal with ordinary traffic and other vehicles. Most of the shops in the area sell clothes. Two designated loading/unloading parking spots are available in this street section, one northbound and the other southbound.

3.5 Survey implementation in the selected area and discussion

The on-site survey has been tested in the designated area for an entire working week, from Wednesday 12th December 2018 to Tuesday 18th December 2018 (Saturday and Sunday excluded). Christmas time was selected as the busiest time of the year for parcel deliveries. Five people of the SUITS team took part in the investigation, with two daily shifts, one going from 10 am to 1 pm and

Table 1 Qualitative and quantitative evaluation of the four aspects of the nine areas

Area #	Number of vehicles	Congestion issues	Street characteristics	Retails locations
1	√	√√	√√	√√
2	√√√	√√√	√	√√√
3	√√	√	√√√	√√√
4	√√√	√√√	√	√√√
5	√√	√√	√√	√
6	√√	√	√	√√
7	√√	√	√	√
8	√√√	√√√	√√√	√√
9	√√	√√	√√	√√

Note: Key: √, low priority; √√, medium priority; √√√, high priority another one from 1 pm to 4 pm. The preliminary scan of GPS recordings presented in the previous section revealed, in fact, that the vast majority of deliveries occur in this timeframe.

Although the collected information cannot be considered as representative of the freight delivery operations in the entire city nor can it be generalized in other ways, it is nevertheless interesting to have a closer look at the survey results in order to understand what could potentially be learned. Overall, 36 different vehicles have been found delivering in this area during the days of investigation, being them cargo vans or box trucks of various dimensions and fueling (mainly natural gas and diesel). Eighty-nine different stop events (according to the definition in section 2.4) were recorded, ranging from 12 to 25 events in each of the 5 days. Their distribution over the day is rather uniform, with an increase in the first part of the morning, when the shops are starting the activity, and in the middle of the afternoon (Fig. 5a). This seems quite surprising, as traffic regulations and restrictions inside the LTZ are, as depicted previously, still designed as if the majority of deliveries occurred early in the morning. Figure 5b reveals the distribution of stop events duration: the average stop duration is 7 min, while their great majority (approximately 70%) lasts less than 8 min. Nineteen out of the above mentioned thirty-six vehicles belong to 6 different express couriers' operators, which in turn made 63 stops out of 89.

The total number of delivery episodes was 123, but also 28 pickups were recorded for an average of 1.7 episodes for each service stop. Figure 6 shows the number of episodes per stop on the y-axis, where stops are ordered from earliest to latest, one bar for each stop. In two cases a commercial vehicle stop has been registered but no goods have been collected or delivered. It is interesting to notice that it is not infrequent to combine more than one delivery or pickup in one stop, despite the above discussed relatively low duration of stops. Also pickup episodes are commonplace. It can therefore be seen on the one hand that freight movements within a city might also involve a non-negligible proportion of "inverse logistics chain", where the goods are moving from consumers or retailers back to dealers or producers. On the other, the small dimension of many deliveries allows not only the consolidation of several service stops into one vehicle tour but also the consolidation of some delivery episodes into one service stop. This aspect of the logistic chain probably deserves more attention, since different final destinations are reached on foot from the location where the vehicle stops. Vehicles understandably tend to stop as much near as possible to the delivery address irrespective of the designated load/unload area, which are also sometimes occupied by private vehicles. This reinforces the idea put forward in the current research to do a spatial cluster analysis of geolocated service stops in order to understand which are the best observation points to run the survey. This can be a support for decision-makers for a possible revision of the related policies, since the actual organization of service stops at least in the considered area is not very effective. Planning for them should consider the actual road space, traffic conditions, density of delivery points of each area, rather than judgmentally scattering them about the road network.

More disaggregated analyses considering the final destinations of the deliveries were also performed. Out of 23 different shops, 10 received parcels on average more than once a day. This figure is strikingly pointing out to which extent logistic chains work just in time and shops in the central area rely on an efficient delivery service to meet the demand for goods, rather than on their stocks. The number of different parcels for those shops ranged from 1 to 47 for the entire week. An average number of 3.5 packages were brought to destination for each delivery episode and 5.8 packages were on average consigned

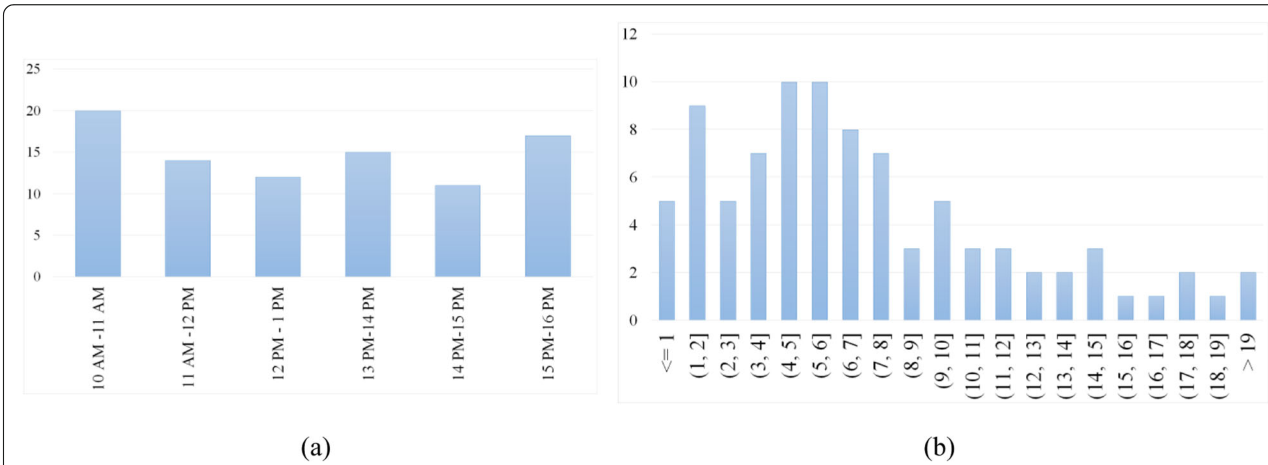

Fig. 5 Distribution of stops events recorded in hour intervals (**a**) and distribution of stop events duration in minutes intervals (**b**)

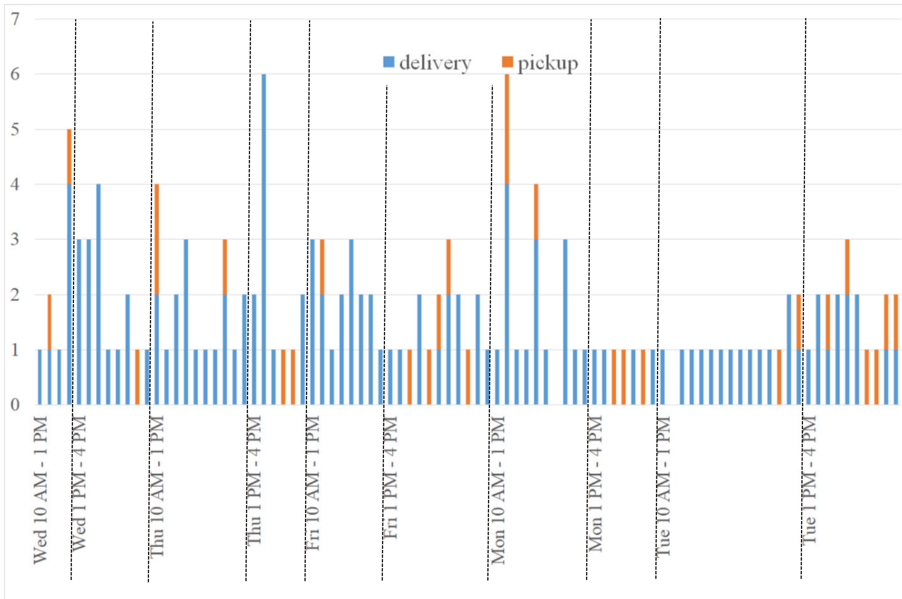

Fig. 6 Number of delivery and pickup episodes for each recorded stop

during each stop event. For each collection operation, instead, we obtain an average number of packages gathered equal to 2.1. 70% of all packages are delivered by hand, even if sometimes they are rather large: the kind of goods sold in those shops (mainly garments or accessories) can be commonly found in bulky but relatively light boxes.

Given the above-discussed fragmentation of operations, an analysis was run to check if parcels commonly delivered by hand after a journey by van could rather be carried using a cargo bike. Limitations on both volume and weights are then to be considered. As stated in section 2.4, the best guess of either the linear dimensions or the volume of packages were recorded too, while it was clearly not possible to gather information on weight through simple visual observation. Even if some assumptions could be done by considering the volumetric weight, a commonly used measure by logistics operators [32], given the above-mentioned kind of goods the volume of packages seems the most limiting factor. We found that 61% of recorded deliveries events correspond to a total volume that can be numerically considered smaller than a cargo bike container of 160 l. Obviously, the parcel size has to fit properly the container dimensions. As depicted also during the data collection operations, cargo bikes are currently delivering in this test site, but with a low daily frequency. Many studies in literature show that a good percentage of motorized trips in European cities could be shifted to bikes or cargo bikes [33], up to 51% according to [34]. These numbers seem to be coherent with our findings. In general, Local Authorities are increasing the promotion of this more sustainable means, as currently happens in Turin. However, it is important a good cooperation between public stakeholders and urban logistics operators [35]. Despite the former aim at increasing the promotion of cargo bikes, the latter are still skeptical, mainly due to operational issues (only cope with small parcels, short travel distance, and availability of consolidation centers).

Although this survey is mainly designed to understand freight demand patterns, it was also noted that the same operator (possibly with different vehicles) delivered more than once from 10 am to 4 pm and up to a maximum of 4 times in this site, which does not seem the ideal situation for efficiency but it is possibly due to scheduling constraints that cannot be assessed through this kind of survey. On the whole, this optimization process is up to the logistics operators and it is out of the scope of our analysis because LAs are not expected to have a say on this directly.

4 Conclusions

The methodology presented, and the real case studied in the city of Turin, have demonstrated how it is possible to use the information of a dataset collecting logistics vehicles GPS traces to effectively sample a manageable number of loading/unloading areas in a city and to run on the latter subset a freight loading/unloading survey. As observed in section 2, works in the literature tend to exploit such kind of dataset for different aims, mainly to investigate the locations of the stops or the freight movement. Instead, the current study tries to show the potentiality of this type of information to practically build the sample, given the fact that designated loading areas are often not used and there is a high spatial dispersion of real service stops in the study area. A spatial clustering analysis was proposed to overcome this issue and it allowed selecting those areas where field observations can maximize the efficiency of the survey effort. Having a good representative sample of all possible freight areas is key to run a detailed investigation that is giving the maximum information with minimal effort. This is a well-known problem of all travel surveys that are extremely expensive and that have therefore to maximize their efficiency. While professional practice in achieving this in passenger surveys is well established, samples of loading and unloading areas are sometimes selected on less rational grounds, thus prejudicing the information quality and insightfulness of the observed data, despite the investment in the data collection activity.

The main interest of the method lies in the possibility for LAs to have a better knowledge of freight distribution patterns at the more disaggregated individual loading/unloading area. Although such information could be theoretically obtained by asking the different operators, it is highly unlikely that it would be fully disclosed due to both data privacy concerns and commercial interests. At the same time, interviews with retailers can be done to collect information about the retail trade in the study area [36]. However, both these approaches require to rely on the cooperation of a sufficient number of retailers and operators to gain an adequate amount of elements useful for the analysis. Given the fragmentation and dynamisms of commodity flows where bulky shipments to a single destination nearly filling one vehicle are the exception, observing unloading parking spots could be more effective.

The proposal of specific policy actions is out the intent of the current work and would require additional investigations and debates with the Municipality; however, we think that some potential exploitation of the current methodology worth to be proposed. In fact, the survey results can be used to inform a range of policy actions at city level related to freight delivery, such as:

- understanding the effectiveness and impacts of delivering operations in key areas of the city,
- assessing the already available unload/load parking spots,
- understanding which actions the LAs should address to ameliorate urban freights policies at specific locations by looking at deliveries in a specific street and at the retailers and shops exploitation of express couriers' services.

Some theoretical developments are probably sought in order to better link the proposed empirical approach with the statistical sampling theory and practice regarding travel surveys and in particular the design of a stratified sample, as commonly happens in Establishment-based Freight Surveys [9]. More specifically, it is possible to explicit consider those variables that were considered to select the areas (area location, urban settings, number of service stops …) as stratifying variables in a stratified sample design (as it is normally done with socioeconomic characteristics to sample individuals in a household travel survey). However, this would be really needed in practice only in case the LA is willing to run the above-described field survey on a substantial sample of, say, several dozens of areas. If this is not the case, e.g. due to budget limitations in running the survey or the research goals that are very specific to a given area, our recommendation is to run a spatial cluster analysis and then to judgmentally select the areas to investigate through an interactive process between municipalities, other stakeholders and analysts, as done in this application.

Concerning the survey contents, its design was influenced by the kind of retail activity which is prevalent in the selected area, namely clothing stores. Different information should probably be gathered in case of different logistic chains, such as groceries, pharmaceutical or newspapers that are characterized by stricter spatial and temporal boundaries that should be properly considered.

The proposed method can be extended (with some adaptation) to any kind of travel survey where the statistical sampling unit are not people but spatial entities, and therefore the stratifying variables cannot be socio-economic characteristics of the user but rather attributes of such entities. Examples include screen-line or cordon surveys where the number of passing points it too high to be entirely surveyed, customer-focused mobility surveys at shops or other attraction points, or even cluster-based household surveys where the analyst desires first to focus and select specific neighborhoods (e.g. those most affected by congestion), before proceeding to build a sample based on socioeconomic characteristics as it is common practice.

Abbreviations

DBSCAN: Density-based spatial clustering of applications with noise; EU: European Union; GIS: Geographic Information System; GPS: Global Positioning System; H2020: Horizon 2020; KPI: Key Performance Indicator; LA: Local Authority; LTZ: Limited Traffic Zone; SUITS: Supporting Urban Integrated Transport Systems: Transferable tools for authorities; SULP: Sustainable Urban Logistic Plan; SUMPs: Sustainable Urban Mobility Plans

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Authors' contributions

Study conception and design: M. Pirra, *M. Diana*; analysis and interpretation of results: M. Pirra, *M. Diana*, A. Woodcook; manuscript preparation: M. Pirra, *M. Diana*, A. Woodcook. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials
The data that support the findings of this study are available from Turin Municipality through 5 T srl but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Turin Municipality through 5 T srl.

Competing interests
The authors declare that they have no competing interests.

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