Feasibility study of urban consolidation centre using traffic data analysis: a preliminary model

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Abstract: The last mile logistics involve the last phase of the supply chain i.e. the delivery to clients (vice versa the first phase of reverse logistics). Its impact is very high in terms of traffic, local air pollutions, noise, greenhouse gas emissions, etc. due to the numerous presence of goods vehicles often characterized by a low level of load saturation. Furthermore the final part of the supply chain is the least efficient and the more expensive of the entire logistics chain.
Logistics distribution in urban areas needs to be optimized to be sustainable. The Urban Consolidation Centres (UCCs) are considered as solutions to solve urban logistics problems: increase in load factor and in service levels, and the reduction of congestion and emissions are the main advantages that these logistics infrastructure entail.
To evaluate sustainability of this part of supply chain specific information are necessary: routes, points of delivery, traffic conditions, number of vehicles, volumes of goods. An analysis based on data from limit traffic zone (LTZ) cameras and on manual data collection allows an initial evaluation on the introduction in the supply chain of UCC. In particular the aim of the paper is to present a preliminary methodology to detect index figures (IF) for the UCCs sizing. Starting from data on vehicles, the goal is to extrapolate IF to compare with other existing realities. The analysis is conducted in a medium Italian city.

Keywords: urban consolidation centre; urban distribution; feasibility study; index figures

1. Introduction

At the beginning of 1970s the research focused on the "transhipment centres" as a solution for the reduction of the heavy goods vehicles (HGVs) in urban areas and for a better load consolidation (McKinnon, 1998a). The first North American transhipment centres were communal, shared-used urban facilities, conceived as public sector initiatives. In the same years, in Dutch cities the urban transhipment centres run by small freight operators working co-operatively and sometimes receiving public financing, but generating low levels of goods throughput (McKinnon, 1998b). In the 1990s, the German small freight operators and forwarders cooperate each other in many cities. In some cases new transhipment centres were built, while in other existing facilities were used (Crainic et al., 2004). In 2005, only five of these facilities were still operating in the following cities: Aachen, Bremen, Essen, Frankfurt am Main and Regensburg (Nobel, 2005).

In the early 2000s in several European countries there was a new interest in the urban transhipment concept: urban consolidation centres (UCCs), freight consolidation centres (FCCs) or urban distribution centres (UDCs) were the new terms for these facilities. These freight transport initiatives intend to reduce goods vehicle traffic, vehicle-related greenhouse gas emissions and local air pollution within urban areas (Allen et al., 2012). Indeed UCCs are logistics facilities located in relatively close proximity to the geographic area that they serve that can be a specific site, a city centre, or an entire urban area.

The objectives of UCC are the avoidance of poorly loaded goods vehicles making deliveries in urban areas and the reduction in goods vehicle traffic thanks to the transhipment and the consolidation of goods at the UCC into vehicles with high load factors for final delivery in the urban area. Furthermore it is possible to operate electric and alternatively powered commercial vehicles for the urban deliveries.

The introduction of an urban consolidation centre affects several aspects. Allen et al. (2012) analyse the pros and cons of UCCs form the perspective of carriers, receivers, UCC operators and the other road users. The freight carriers employ less time to make the deliveries to UCC leading to better vehicles utilization. Some disadvantages for the freight carriers are the insertion of a new handling goods and the reduction in direct contact with customers. The number of vehicles near the UCC increases and thus also the level of traffic. But there are also some advantages for the road users: the reduction in total unloading time at delivery point and the reduction in total goods vehicle trips and km. On the traffic side, it is possible to achieve the reduction in local traffic problems near the points of delivery. For the receivers, the reliability in delivery times from UCC is improved: the deliveries are fewer but larger, so the receivers spent less time to receive the goods. From the point of view of traffic and environmental impacts, UCCs can reduce the total distance travelled in urban areas and therefore the greenhouse gas emission and the local air quality pollutants having a better load factor of commercial vehicles used for the deliveries. In addition, the better load factor reduces the impact of freight operations on traffic congestion (Boudouin, 2006; Browne et al., 2005; Gonzalez-Feliu & Morana, 2010; WSP, 2008). The improvements refer only to the transport activities that take place from the UCC and the final point of delivery.

In the paper a study concerning a possible UCC in a medium city in Italy is considered. Figure 1 shows a schematization of the city, with its centre and its suburban area. With the presence of the UCC all the commercial vehicles that distribute goods would arrive at the facility and from there they would start again for delivery to the final customers. Analysing and collecting data regarding the traffic, the purpose is to verify the expediency of setting up the UCC.

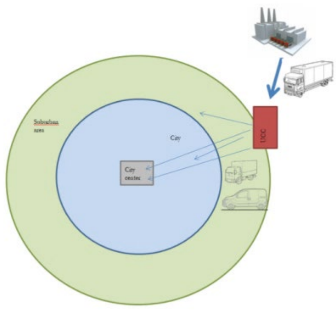

Figure 1: City schematization with a UCC

In particular the aim of the paper is to present a methodology to detect index figures (IF) for the UCCs sizing. Starting from vehicle counting, the goal is to extrapolate IF to compare with other existing realities, obtaining useful information for the feasibility study of the UCCs. The model presented is at preliminary stage.

The remaining of the paper is organized as follows: Section 2 is dedicated to a review of literature about UCCs, while Section 3 contains a depiction of the methodology used. Section 4 is dedicated to presentation of the case study, while in Section 5 results are presented and discussed. Section 6 contains the conclusions.

2. Literature review

Mobility and urban freight activities form a complex system within urban areas. Moeinaddinia et al. (2015) introduced an Urban Mobility Index (UMI) for the evaluation of transportation in cities: at macro-level the urban structure variables correlated with the percentage of daily trips were investigated. On the basis of correlation results, the UMI, with range from 0 to 100, was evaluated. In this manner it was possible to evaluate if the mobility was sustainable (high values) or no (low values). UMI seemed to be effective for a quick evaluation about a city, even if it was based on macro-level variable and there was not distinction between transportation of goods or people.

In Anderson et al. (2005) it was underlined that urban freight transport impacted the economy, the sociality, the environment. They collected data from 120 vehicle rounds and 2286 collections and deliveries from 3 different cities. In this manner the impact of 4 policies measures (Low Emissions Zones, Congestion Charging, Weight Restrictions, and Time Restrictions) was evaluated. Even if in the paper there were interesting suggestions and insights the benefits of the 4 policies, measures were not completely quantified. Cherrett et al. (2012) analysed 30 surveys about urban freight activity in UK searching correlated factors. The average number of deliveries per week to establishments and the mean number of goods delivery by business and other interesting factors were estimated. Those factors can be useful for understanding the freight activities and also for the design of facilities like UCCs. They referred only to the UK context and factors provided, averaged data, were useful only at the very first stage of the analysis.

Although there were different measures of intervention and initiatives in the city logistics (a classification is shown in De Marco et al., 2017), our research has focused on an infrastructural initiative, i.e. the UCCs.

In de Oliveria et al. (2012) a preference technique and adoption theory based model for retailer and carrier was considered. Thanks to this model it was possible to identify for a particular city what were the more important attributes an urban distribution centre (UDC) must address. Application of the model to 2 Brazilian cities showed that for carriers the more important attribute was parking while for retailers costs attribute were contrary to the UDC schemes.

Janjevic and Ndiaye (2014) concerned the very interesting subject of Micro Consolidation Schemes, logistics platforms within urban area. They represented something different from UCC which are usually located outside the city centre. It was some sort of UCC downscaling. Micro consolidation schemes were then similar to the UCC considered in this paper, because was thought for a small Italian city. There were 6 main typologies of Micro-Consolidation Centres. While there were many project developing Micro-Consolidation initiatives, main issue was about the transferability. Transferability meant the possibility to transfer a micro-consolidation centre successful solution to another place. Authors proposed a framework for such transferability. They applied the framework to the City of Brussels where they showed the feasibility of a micro-consolidation solution and they found the best location within the city. Nevertheless the paper did not cover in detail the issue of the volume and flows of traffic within the urban area.

In van Duin et al. (2010) the important factors for the success and failures of UCC were identified: Number of Users, Organization, Subsides, Type of Vehicle, Location and Accompanying Measures. Authors investigated several UCCs projects and they found that one of the main problems is the cooperation between transportation companies using the UCCs. For transportation companies phases like picking and delivery of goods to the clients were part of their core business. It was not so simple, then, to outsource those activities. Furthermore they should share very sensitive information with other competitors. A feasibility study of an UCC was considered and several scenarios were discussed. Evaluations were based only on average statistical data about goods and deliveries without any traffic measurements.

In Paddeu et al. (2014), an analysis of an existing UCC (Bristol-Bath) was shown, based on a database of goods and deliveries data for a period of 17 months. A Multiple Linear Regression model was developed to correlate the number and the type of heavy goods vehicles delivering to the UCC with the number of deliveries. The regression was good and could be useful in the planning of the UCC. Modelling and Simulation can support UCCs design like any other logistics facility. In Bruzzone et al. (2015), for instance, a simulation tool for the design of harbour terminal was considered. UCCs had many common aspects with harbour terminal even if they were usually smaller: flows management, loading and unloading and housekeeping operations etc. But for other aspects they differed a lot. In harbour terminal the goods flows concerned mainly containers, while in UCCs goods were mainly parcels.

Is to be noted the lack of studies and research in literature that allow the sizing of the UCCs starting from data on the goods delivered or commercial vehicles. For example, there are no IF that allow a sizing estimate for an initial feasibility study on the implementation of the UCCs.

3. Research approach

To reach the objective of the paper, the detection IF for UCCs sizing, the approach shows in Figure 2 is followed. Figure 2 points out the research steps (boxes on the left) and the considerations and assumptions made (boxes on the right). After the vehicles counting, an estimate of the total traffic is made by hypothesizing some data. Further assumptions on volumes transported and number of parcels are necessary to define the IF.

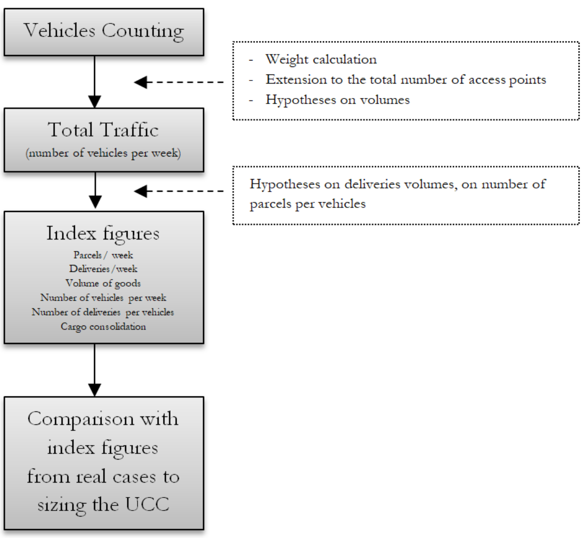

Figure 2: Research steps

3.1 Traffic counting

Traffic counting determines the number and classifications of vehicles at specific locations and times. In particular, vehicles used for commercial purposes (i.e. mini-van, van, light trucks, trucks and heavy trucks) are of greater interest for the research as they would be possible users of the UCC.

There are two methods for counting traffic: manual and automatic.

Automatic counting uses the data given by the cameras placed at several points in the city. The cameras identify a vehicle and classify it according to the form. The classification is already set in the data recording software system and it considers the following vehicle classes: motorcycles; cars; mini-van and van; light trucks and trucks; buses; heavy trucks.
The classification of the vehicles shape is not always corresponding to reality. For example, some cars of great size can be classified as a van and then incorrectly classified as commercial vehicles.

Manual counting is based on visual examination by individual observers. The data are usually recorded using tally sheets or mechanical counters. After data have been collected for an interval (15 minutes), totals are calculated and registered on a data sheet which can be input into computer later. In the case study the measurements of the all vehicles travelled to the city centre, are tracked for a period of two weeks. Two time windows are measured: in the morning from 7.00 to 10.00 and in the afternoon from 14.30 to 16.30.

The classification of the vehicles is the following: motorcycles; cars and taxis; mini-van; van; light trucks; trucks; mini-van and van (services); buses; light trucks and trucks (services); cars (services).The just listed classification includes a distinction for vehicles used for some services (electricity, telephone, cleaning, …). In this way the classification is more efficient and the data collected on commercial vehicles considers all the real vehicles that deliver goods.

It is important to underline that the locations of the two methods are different. On one hand the automatic counting analyse several points using many cameras around the city centre and the suburban area. On the other hand the manual counting is located at only one point. The choice of this point depends on the first analysis of the data come from the automatic counting: the manual measures are made at the busiest access point to the city centre.

3.2 Total traffic

To estimate the total number of commercial vehicles that enter the urban area, an estimate is made. It is evaluated the weight of each of the commercial vehicles categories (mini-van and van, light trucks and trucks, buses) compared to the total considering the data obtained from manual measurement. Subsequently the weights are multiplied by the total of commercial vehicles detected by the LTZ cameras placed on all the enter points to the city center: the total number of commercial vehicles is obtained. This calculation makes it possible to estimate the total number of commercial vehicles. In fact it is not correct to use the data deriving from the automatic counting due to errors in reading the size of the vehicle nor only the manual counting because it refers to a single entrance to the city center.

3.3 Index figures

From a series of IF of commercial traffic of a certain area, it is possible to obtain IF for the general sizing of the UCC.

The considered IF of the commercial traffic are the following:

- Number of deliveries per vehicles (IF_1);
- Deliveries/week (IF_2);
- Volume of goods per week(IF_3);
- Cargo consolidation (IF_4);
- Parcels/ week (IF_5).

To calculate the IF some assumption and hypothesis are made:the total cubic meters of goods circulating in the city center are calculated considering the maximum load size for each commercial vehicle and assuming the cargo consolidation; knowing or assuming deliveries or cargo consolidation , it is possible to estimate the total volume of goods delivered.

4. Case study

The case study concerns the urban logistics of a medium Italian city, analysing the amount of traffic inside the city centre and the suburban area. All the recorded and measured data are shown in Caldarelli (2017).

4.1 Automatic counting

In collaboration with the municipality the recorded data of the cameras were collected. Figure 3 shows the position of the cameras in the city. In Figure 3, the green point are only access point, the red ones are only exit points, while in black the points where the vehicles can enter and exit the city centre. All of these points are the gates of the limit traffic zone (LTZ) area.

Figure 3: Cameras positions in the city centre

Analysing the data of the cameras for a period of 30 months (from January 2013 to June 2015), some problems in the recording of data are highlighted: malfunctioning or not yet functioning of some cameras. Therefore, the analysis focused on the 12 months of 2014 as the data of all the gates were available and the monthly average is calculated.

For greater clarity in reading the data, only the data relating to commercial vehicles (mini-van, van, light trucks, trucks and heavy trucks) entering the access point to the city centre are shown in Table 1.

Table 1: Data from cameras, monthly average

	Type of transport			
Gate	Mini-van, van	Light trucks, trucks	Heavy trucks	Total
1	4.908	6.206	92	11.207
3	281	174	0	455
5	4	0	2	6
6	960	97	0	1.058
7	438	0	16	455
8	2.675	3.482	30	6.188
12	178	30	0	208
14	3	1	0	5
15	35	1	0	37
TOTAL	9.484	9.991	142	19.616

The focus on only access points is necessary to know the number of the vehicles that could use the UCC. Among these, it is clear that the point of greatest interest is point 1, being the point with the greatest number of vehicles (57% of the total). The total number of vehicles entering the city center area is 19.616 commercial vehicles.

4.2 Manual counting

Starting from the considerations made in Section 4.1, a manual counting of the vehicles entering the area of the city centre has been done. For two weeks, from 7.00 a.m. to 10.00 a.m. and from 2.30 p.m. to 4.30 p.m., all the vehicles entering the access point 1 to the city centre are counted.

Table 2 shows the daily average collected data by manual counting.

Table 2: Manual counting, daily average

	Manual counting
Motorcycles	305
Cars, Taxis	1096
Mini-Van, Van	182
Light Trucks and trucks	55
Bus	63
Total	1702

The total daily average number of commercial vehicles is equal to 300. Buses are also included to correct the error of the automatic counting due to errors in reading the size (buses and heavy trucks are often confused).

5. Results and discussions

Since the measured data refer to only one access point to the city center and since relying only on automatically detected data leads to evaluation errors, an estimate of the total number of commercial vehicles entering from all access points to the city center is made. Starting from the data measured manually, the weight of each category (W_i) of commercial vehicles is calculated on the total of average commercial vehicles per day (see Equation 1 and Table 3).

$$W_i = \frac{\text{daily average category i}}{\text{total daily average}} \quad (1)$$

Multiplying each weight by the total of the incoming commercial vehicles for all access points (19.616 vehicles, data deriving from the automatic measurement), the estimate of the total commercial vehicles per week (NVW) is obtained: 2.373 (see Equation 2 and Table 3).

$$NVW = \frac{W_i \cdot 19.616}{4} \quad (2)$$

To calculate the maximum volumes of goods per week (MVGW, Equation 3), the maximum load capacity for each category of commercial vehicles is considered. The volumes obtained are shown in Table 3.

$$MVGW = NVW \cdot CC \quad (3)$$

Table 3: Estimate of commercial vehicles and calculation of volume of goods

Vehicles Categories	Cargo capacity (CC) [m³]	Weight (W_i) *	Number of vehicles per week (NVW) **	Max. volume of goods (MVGW) [m³/week] *
Light trucks	18	0,094	463	8.334
Trucks	38	0,012	60	2.280
Van	7	0,179	876	6.132
Mini-van	5	0,199	974	4.870
Total			2373	21.616

* calculated

** estimated

A previous survey carried out in 2006, interviewing 367 of 490 shops in the same city centre, measured the average daily deliveries equal to 290 (City Logistics, 2006). Therefore, considering the estimated number of commercial vehicles during a week, two IF are calculated:

$$IF_1 = \frac{490}{367} \cdot \frac{2.373}{(290 \cdot 6)} = 1{,}82 \quad (4)$$

$$IF_2 = 2.373 * IF_1 = 4.319 \quad (5)$$

IF_1 (Equation 4) represents the number of deliveries per vehicles while IF_2 (Equation 5) the total deliveries per week.

Assuming the volume for each deliveries equal to 0,26 m^3 (Burlando, 2003), the total volume of goods delivered (IF_3) per week is 1.123 m^3/week (Equation 6)

$$IF_3 = IF_2 * 0{,}26 = 1.123 \quad (6)$$

It is possible to calculate the cargo consolidation (Equation 7, IF_4), considering the ratio between the maximum volume of goods delivered by commercial vehicles (21.616 m^3/week) and the estimated volume (IF_3).

$$IF_4 = \frac{IF_3}{21.616} = 0{,}05 \quad (7)$$

To estimate cargo consolidation it could be also used the data provided by the case study of The Hague (about 2 m^3/delivery): this data it is not applicable for our case and it indicates the diversity of goods delivered between the two cities.

Assuming a number of parcels per vehicle equal to 5 (Burlando, 2003) the total number of parcels per week (IF_5) is expressed by Equation 8:

$$IF_5 = IF_2 * 5 = 21.594 \quad (8)$$

To assess the goodness of the estimates and to determine IF useful for the size of the UCC, an analysis of real cases of urban consolidation center is made: The Hague (van Duin et al., 2010), Lucca (Ambrosino et al., 2011), Genova (Burlando, 2003), Padova (Cityporto, 2015), Ferrara (Progetto City Logistics Ferrara, 2007), Parma (Infomobility, 2012), Luxemburg city and Esch-Alzette (Leonardi et al., 2015) are examined.

Table 4 shows data relating to measurements and estimates of freight traffic in terms of volumes and commercial vehicles, carried out in cities where a UCC was then created. These data are reported in the same unit of time (a week) to have a better comparison: it is assumed 1 year composed of 52 weeks, 1 month of 30 days and 1 week of 6 days.

Data relating to the UCCs implementation phase are also reported (Vaghi and Percoco, 2011). There are few data (Table 4 contains many missing data indicated with "n.a." i.e. not available) and, if there are any estimates, there is a discrepancy between the number of goods and vehicles, as well as between the number of deliveries made and the size of the UCC (Genova and Padova).

It is therefore very difficult to identify IF, which would be useful in the feasibility study of a UCC. In particular it is possible to note that:

- The data in the literature are very limited, both in terms of sizing and operational, and cover very different realities.

- The two cases that present more data (The Hague and Genova), in fact, show very different values of characteristic sizes, due essentially to a different volume per delivery.

- The derivation from traffic counting (therefore from an estimate of vehicle numbers) of a rough dimensioning of a UCC can be done only referring to the two cases mentioned above (Genova and The Hague), which as shown have very different IF between of them

In any case, an initial estimate of the UCC size is made based on the case of Genova, obtaining a surface area of 1.518 m².

Table 4: Data from existing UCCs. Calculation and estimate of the case study

	The Hague	Lucca	Genova	Padova	Ferrara	Parma	Luxemburg city and Esch-Alzette	Perugia
Parcels / week	n.a.	n.a.	49.800	n.a.	n.a.	n.a.	7.200	21.594 **
Deliveries / week	2.858	6.400	9.960	1.956	n.a.	n.a.	n.a.	4.319 *
Volume of goods [m³/week]	4.653	n.a.	2.590	n.a.	n.a.	n.a.	n.a.	1.123 **
Number of vehicles per week	397	10.080	n.a.	n.a.	31.266	12.212	n.a.	2.373 **
Number of deliveries per vehicles	7,2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,82 *
Cargo consolidation	n.a.	<30%	n.a.	n.a.	n.a.	n.a.	n.a.	5% **
Target gruop	531 shops	city centre	city centre	n.a.	city centre	n.a.	n.a.	city centre
Operative UCC								
Deliveries / week	n.a.	660	n.a.	1.154	4.667	167	n.a.	
Cargo consolidation	n.a.	>60%	n.a.	n.a.	n.a.	n.a.	n.a.	
Surface [m²]	388	n.a.	3.500	1.000	n.a.	1.500	300-400	1.518 **

* calculated
** estimated

6. Conclusions

In the paper an UCC is considered as solution for the urban freight transportation in a medium Italian city. The aim of these logistics solutions is to reduce the goods vehicles traffic, taking advantage of the transshipments and the consolidation of goods at the UCC into vehicles with high load factors for the deliveries in the urban areas.

The analysis of 30-month traffic data given by cameras placed at several points in the city and the manual counting carried out for 2 weeks, allowed to make a preliminary evaluation on the sizing of the UCC.

The methodology applied is the utilization of IF for the UCC sizing. However, IF for this purpose are still very scarce and with very different trends depending on the logistic context. It should be noted that the estimated cargo consolidation is low and it allows a large margin of improvement with the use of UCC. This is also linked to the fact that the data collected manually relate to a single access point. Although vehicle counting has been extended (as described in Section 3), it may be appropriate to measure other points in order to validate the hypotheses made in this work.

The detection of IF for the size of the UCCs is still an aspect to be explored in future research, being a research field that deserves considerable attention.

Obviously other aspects are to be evaluated, such as the position or the use of green vehicles (powered by natural gas or electricity) to distribute goods. After establishing the position of the UCC and the type of vehicles used, it is possible to make a static simulation (Saetta and Caldarelli, 2016) to evaluate the environmental benefits.

It could also be considered the time spent in unloading goods from the incoming vehicles at the UCC and loading the goods into the high load factor vehicles for final deliveries, evaluating the possible temporal delays.

All these considerations will be the subject of future research.

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