URBAN LOGISTICS: THE ROLE OF URBAN CONSOLIDATION CENTRE FOR THE SUSTAINABILITY OF TRANSPORTATION SYSTEMS

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ABSTRACT
In the paper urban consolidation centres (UCCs) are considered as solution for the urban freight transportation. After a short related research concerning UCCs, a case study about a medium Italian city is considered. Static simulation is used to evaluate the environmental benefits of UCC due to freight consolidations and electric vehicles. Results show that the environmental effectiveness of UCCs depends on the level of cargo consolidation. Considering for instance cargo consolidation of 80%, a saving of 30% of emissions is possible.

Keywords: urban consolidation centre, freight consolidation, urban transportation simulation, logistics simulations

1. INTRODUCTION
Urban consolidation centres (UCCs) could play an important role in the future sustainability of the cities. Up to now, the studies of urban consolidation centres show that they could be effective in reducing the urban traffic but the economic viability is always under discussion. This mainly because UCCs could increase logistics costs. Several possible solutions are studied. It is anyway interesting to plan the possibility to introduce UCC, also in medium-small cities in Italy. Thanks to IT technologies and to improvements in alternative fuels such as electric cars, UCCs will become more attractive in the future.
In the paper a study concerning a possible UCC in a medium city in Umbria is considered. In particular a simulation model based on Cube software shows the potential benefit of the introduction of UCC.
In Section 2 a related research concerning UCC is shown. In Section 3 the case considered is depicted and results of different UCC scenarios are shown. In Section 4 conclusions are drawn.

2. RELATED RESEARCH
Modeling 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 harbor terminal is considered. UCCs have many common aspects with harbor terminal even if they are usually smaller: flows management, loading and unloading and housekeeping operations etc. But for other aspects they differ a lot. In harbor terminal the goods flows concern mainly containers, while in UCCs goods are mainly parcels.
In Van Duin, Quak and Muñuzuri (2010) the important factors for the success and failures of UCC are identified: Number of Users, Organization, Subsides, Type of Vehicle, Location and Accompanying Measures. Authors investigate 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 are part of their core business. It is not so simple, then, to outsource those activities. Furthermore they should share very sensitive information with other competitors. A feasibility study of an UCC is considered and several scenarios are discussed. Evaluations are 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) is shown, based on a database of goods and deliveries data for a period of 17 months. A Multiple Linear Regression model is developed to correlate the number and the type of heavy goods vehicles delivering to the UCC with the number of deliveries. The regression is good and could be useful in the planning of the UCC. Also Environmental Emissions reductions are estimated. The UCC is successful, but since the take-up was slower than forecasted, emissions reduction at the time of the paper were limited.
In Leonardi et al. (2014) a best practice methodology for UCC is considered. A Multi Criteria Analysis based on 4 criteria is shown: Innovation and Technical and Economic Feasibility, Strength of External impact, Accessibility of Information, Transferability of Best Practices. 15 cases chosen from 93 are analyzed. Results are interesting but they need more cases to be validated scientifically.
Janjevic and Ndiaye (2014) concerns the very interesting subject of Micro Consolidation Schemes, logistics platforms within urban area. They represent something different from UCC which are usually

located outside the city centre. It is some sort of UCC downscaling. Micro consolidation schemes are then similar to the UCC considered in this paper, because is thought for a small Italian city. There are 6 main typologies of Micro-Consolidation Centres. While there are many project developing Micro-Consolidation initiatives, main issue is about the transferability. Transferability means the possibility to transfer a micro-consolidation centre successful solution to another place. Authors propose a framework for such transferability. They apply the framework to the City of Brussels where they show the feasibility of a micro-consolidation solution and they find the best location within the city. Nevertheless the paper does not cover in detail the issue of the volume and flows of traffic within the urban area.

Moeinaddinia et al. (2015) introduces an Urban Mobility Index, UMI, for the evaluation of transportation in cities. First of all at macro-level the urban structure variables correlated with the percentage of daily trips are investigated. They found 18 variables with significant correlations: Urban population density, Length of road per thousand of inhabitants etc. On the basis of correlation results the UMI, with range from 0 to 100, is evaluated. In this manner it is possible to evaluate if the mobility is sustainable (high values) or no (low values). UMI seems to be effective for a quick evaluation about a city, even if is based on macro-level variable and there is not distinction between transportation of goods or people. In Anderson et al. (2005) it is underlined that urban freight transport impacts the economy, the sociality, the environment. They used 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, Time Restrictions) is evaluated. Even if in the paper there are interesting suggestions and insights the benefits of the 4 policies, measures are not completely quantified. Furthermore paper does not consider the possibility to reduce traffic via an urban consolidation centre.

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

In Browne et al. (2011) an interesting micro consolidation centre trial in London is depicted. The trial shows that it is possible to reduce the emissions by using electric vehicle even if the kilometers travelled within the city increases. This because of the reduced capacity in weight and volume of the electric vehicles. Operating costs does not increase with the micro consolidation centre. In more detail the increase of costs concern the distribution centre operating costs (because of the micro consolidation centre) and driver costs. The decrease of costs concern vehicle capital, insurance, maintenance and fuel costs.

Cherrett et al. (2012) analyses 30 surveys about urban freight activity in UK searching correlated factors.

They estimated the average number of deliveries per week to establishments; the mean number of goods delivery by business and other interesting factors. They make a distinction between goods deliveries to establishment and service visits to establishments. Those factors can be useful for understanding the freight activities and also for the design of facilities like UCCs. They refer only to the UK context and factors provided, averaged data, are useful only at the very first stage of the analysis.

In Allen et al. (2012) UCC benefits are: reduce goods vehicle traffic, vehicle related greenhouse gas emissions and local air pollution.

UCCs are logistics facilities for transshipping and consolidating goods. In this manner vehicles can reach high load factors for the final delivery in the urban area.

Electric goods and alternatively powered vehicle can further reduce the environmental impact. Another important distinction is that there are several types of UCC: serving all or part of an urban areas, UCC serving large site with a single landlord and UCC consolidating construction materials. Only the second type, with single landlord (airport, big hospitals, etc.) can reach easily an economic feasibility. For UCC of type one success depends on several factors above all the number of retailers participating to the initiative.

It is important in the UCC analysis to consider the kind of good transported. In the present paper mainly non fresh food is considered. For fresh food, in Bruzzone and Longo (2014) there is an interesting application methodology for the logistics and transportation in the fresh food supply chain.

3. CASE CONSIDERED

The case study concerns the urban logistics of a medium Italian city. Starting from the actual scenario of goods distribution, several scenarios are analysed with the aim of reducing the number of vehicles and the quantity of emissions. The study focus on the city centre, where local environmental and traffic problems are more noticeable.

To obtain data about the actual goods distribution system, a data collection was made in the limit traffic zone (LTZ) area. After a preliminary analysis of the LTZ input gates, four gates are considered for the vehicles counting.

For 10 days, from 7.00 a.m. to 11.00 a.m., all the vehicles entering the city centre through the 4 input gates are counted. Table 1 shows the daily averaged collected data. The commercial vehicles are classified in these categories:

- Mini – Van
- Van
- Light trucks (< 3.5 tons)

- Trucks (> 3.5 tons)

Some light trucks and trucks are not used for commercial activities but for other services like the vehicles of cleaning companies or construction firms. These vehicles are classified separately from the others and they are indicated with "services".
From 7.00 a.m. to 11.00 a.m. 2593 vehicles enter the city centre. Of these 283 are commercial vehicles.
The peak hour is from 07.45 to 08.45 a.m.: 88 commercial vehicles on a total of 915 vehicles.

Table 1: Collected Data

	Cars, taxi	Motorcycles	Mini-van	Van	Light Trucks	Trucks	Bus	Light trucks (services)	Trucks (services)	Total
07:00	39	3	2	4	3	1	6	0	0	58
07:15	52	3	4	2	4	0	13	1	0	79
07:30	117	24	9	6	2	0	10	0	0	168
07:45	212	39	18	13	6	0	11	1	0	300
08:00	187	18	7	5	3	0	10	1	1	232
08:15	153	20	15	5	0	0	10	1	0	204
08:30	133	22	10	3	3	0	7	1	0	179
08:45	115	34	11	2	2	2	9	2	1	178
09:00	142	21	15	4	0	1	15	0	0	198
09:15	117	19	8	2	3	1	11	3	0	164
09:30	104	20	11	5	1	1	9	0	0	151
09:45	102	19	17	2	5	1	12	0	0	158
10:00	80	21	9	3	1	0	6	1	1	122
10:15	87	19	6	2	3	1	11	3	0	132
10:30	94	12	11	5	8	0	9	0	0	139
10:45	89	12	8	5	2	0	11	4	0	131
Total	1823	306	161	68	46	8	160	18	3	2593

To simulate the actual and other scenarios, the Cube software (Cube 6.0, Citilabs Inc.) is used. The version used allows the modelling of the distribution of vehicles on the road network of the city. The city is divided into different traffic zones and then an O/D matrix is built to represent the movements between those zones. Each (i,j) element of the matrix represents the number of vehicles having the zone i as the origin and the j zone as destination. The model treats the road network as a graph, which consists of arcs and nodes. To each arc is assigned a vehicular load on the basis of a mathematical law, the choice of which depends on the type of network and the type of mobility that characterizes the area. However, the user can choose the most cost-effective route, taking into account rational behaviour and user needs. In the case study, the assignment is made on the basis of actual traffic flows counted in the input gates of LTZ.
In the case study, 8 zones are detected:

- Zone 1: the city centre, the destination of all the vehicles;
- Zone 2: a freight village, a possible origin zone for alternative scenarios;
- Zones 3-8: the main access routes to the city.

To simulate the traffic, the software needs of the weighted sum of the vehicles, where the weight is relative to the size. For motorcycles the weight is 0.5; for cars, mini-vans and vans the weight is 1; for light trucks the weight is 1.5 and for trucks and buses is 2.5.
Regarding the peak hour and only the commercial vehicles, the total commercial equivalent vehicles are 94.

3.1. Actual Scenario

Figure 1 shows the actual schematization of the city centre (1) with the four gates (a, b, c and d) and the main access route (3-8). The freight village (zone 2) is not used. The numbers next to the arrows refer to equivalent vehicles passing between the origin and destination linked by the arrow. Table 2 is the O/D matrix for the actual scenario. The showed flow of vehicles is assumed.

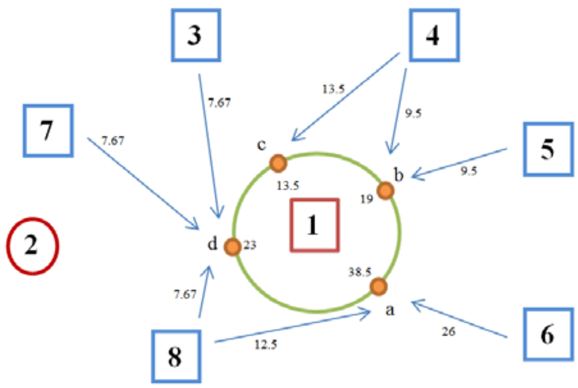

Figure 1: Actual Scenario

Table 2: O/D matrix for the actual scenario

Origin	Destination				
	a	b	c	d	Total
3	0.00	0.00	0.00	7.67	7.67
4	0.00	9.50	13.50	0.00	23.00
5	0.00	9.50	0.00	0.00	9.50
6	26	0.00	0.00	0.00	26.95
7	0.00	0.00	0.00	7.67	7.67
8	12.5	0.00	0.00	7.67	19.22
Total	38.50	19.00	13.50	23.00	94

3.2. UCC Scenarios

The study aims to use the UCC in the distribution of goods in the city centre. Different scenarios which include the UCC are analyzed. A first scenario called "UCC scenario" is taken as the basis for the comparison with the other scenarios.
Figure 2 shows the UCC scenario where the urban consolidation centre is used in the freight delivery system of the city. The UCC is denoted in the figure by zone 2. Knowing the data collected, the following assumptions are made to trace the number of vehicles traveling:

- Only about 65% of the total vehicles diverts to the UCC. So on the average 61.1 vehicles travels from UCC to the city centre.
- All the vehicles originating from zone 3 are shifted to UCC.
- Only 60% of the vehicles originating from zone 4 are shifted to UCC.
- Only 40% of the vehicles originating from zone 5 are shifted to UCC.
- Only 30% of the vehicles originating from zone 6 are shifted to UCC.
- All the vehicles originating from zone 7 are shifted to UCC.
- All the vehicles originating from zone 8 are shifted to UCC.

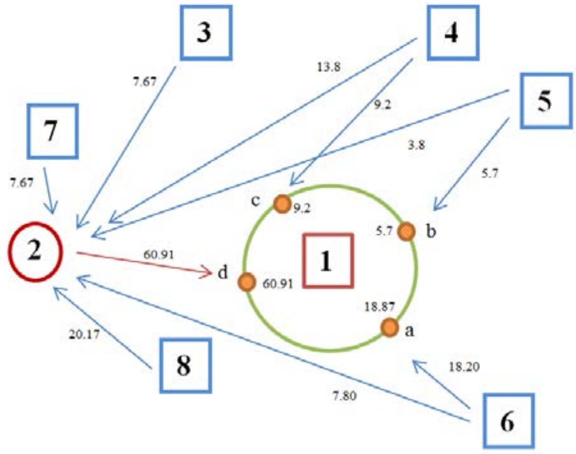

Figure 2: UCC Scenario

Considering all these assumptions, in Figure 2 the numbers next to the arrows refer to equivalent vehicles passing between the origin and destination linked by the arrow.
The O/D matrix in Table 3 refers to the movements from the different zones to the city centre for the UCC scenarios.

Table 3: O/D matrix for UCC Scenario

Origin	Destination				
	2	a	b	c	d
2	-	0.00	0.00	0.00	60.91
3	7.67	0.00	0.00	0.00	0.00
4	13.80	0.00	0.00	9.20	0.00
5	3.80	0.00	5.70	0.00	0.00
6	7.80	18.20	0.00	0.00	0.00
7	7.67	0.00	0.00	0.00	0.00
8	20.17	0.00	0.00	0.00	0.00

For the other scenarios involving the UCC, assumptions about the type of vehicles used and on the load consolidation are made.
Regarding the type of vehicles, Electric Scenario involves the use of electric vehicles from the UCC.
The assumptions on load consolidation, consider three scenarios. In the Optimistic Scenario the vehicles are filled to 80%, in the Intermediate Scenario they are filled to 50% and in the Pessimistic Scenario the vehicles are filled to 20%. The UCC Scenario considers a load consolidation of 30%.
To compare the UCC Scenario with the alternative ones, EMISMOB, an integrated module of Cube software, is used. EMISMOB aimed at quantifying the consumption and emissions of pollutants, it is possible to know the amount of fuel consumed by passing vehicles, and the amount of emissions (NO_x: oxides of nitrogen and their mixtures, CO: carbon monoxide, PM10: Particulate Matter, SPM: suspended particulate matter, CO_2: carbon dioxide, N_2O: nitrogen monoxide, CH_4: methane). Table 4 shows fuel consumptions and emission for the UCC scenario.

Table 4: Fuel Consumptions and Emission for the UCC Scenario

UCC Scenario				
	Zone 1-8		Zone 1	
Fuel Consumption	35,585.66	g/h	4,278.01	g/h
NO_x	664.33	g/h	79.86	g/h
CO	437.81	g/h	52.63	g/h
PM10	62.59	g/h	7.52	g/h
SPM	70.82	g/h	8.52	g/h
CO_2	111,798.99	g/h	13,440.16	g/h
N_2O	1.91	g/h	0.23	g/h
CH_4	2.69	g/h	0.32	g/h

3.2.1. Electric Scenario

The Electric Scenario uses electric vehicles to deliver the goods from the UCC (zone 2) to city centre (access point *d*). All other deliveries are made with diesel vehicles. The electric vehicles produce no emissions or fuel consumption. Fuel consumption and emissions for this scenario are due to the diesel trucks (see Table 5).

Table 5: Electric Scenario

Electric Scenario					
	Zone 1-8		Zone 1		Reduction
Fuel Consumption	33,293.95	g/h	1,378.54	g/h	68%
NO_x	621.43	g/h	25.72	g/h	68%
CO	409.65	g/h	16.97	g/h	68%
PM10	58.56	g/h	2.42	g/h	68%
SPM	66.25	g/h	2.74	g/h	68%
CO_2	104,599.15	g/h	4,330.95	g/h	68%
N_2O	1.79	g/h	0.07	g/h	70%
CH_4	2.52	g/h	0.11	g/h	66%

The comparison with the UCC Scenario is reported in terms of percentage reduction.

3.2.2. Optimistic Scenario

The Optimistic Scenario uses traditional vehicles to deliver the goods from the UCC (zone 2) to city centre (access point *d*). The assumption on the consolidation load of 80%, implies that on the average 22.84 vehicles leave the UCC towards the city centre (the number of vehicles decreases of 62.5%). Fuel consumption and emissions for this scenario are due to the diesel trucks (see Table 6).

N_2O	4.51	g/h	0.42	g/h	83%
CH_4	6.36	g/h	0.59	g/h	84%

The comparison with the UCC Scenario is reported in terms of percentage increase.

Table 6: Optimistic Scenario

Optimistic Scenario					
	Zone 1-8		Zone 1		Reduction
Fuel Consumption	45,968.,20	g/h	2,962.83	g/h	31%
NO_x	858.08	g/h	55.31	g/h	31%
CO	565.56	g/h	36.45	g/h	31%
PM10	80.85	g/h	5.21	g/h	31%
SPM	91.48	g/h	5.90	g/h	31%
CO_2	144,417.69	g/h	9,308.27	g/h	31%
N_2O	2.47	g/h	0.16	g/h	30%
CH_4	3.48	g/h	0.23	g/h	28%

The comparison with the UCC Scenario is reported in terms of percentage reduction.

3.2.3. Intermediate Scenario

The Intermediate Scenario uses traditional vehicles to deliver the goods from the UCC (zone 2) to city centre (access point *d*). The assumption on the consolidation load of 50%, implies that on the average 36.55 vehicles leave the UCC towards the city centre (the number of vehicles decreases of 39.9%). Fuel consumption and emissions for this scenario are due to the diesel trucks (see Table 7).

Table 7: Intermediate Scenario

Intermediate Scenario					
	Zone 1-8		Zone 1		Reduction
Fuel Consumption	53,566.22	g/h	3,912.58	g/h	9%
NO_x	999.84	g/h	73.03	g/h	9%
CO	659.07	g/h	48,14	g/h	9%
PM10	94.21	g/h	6.88	g/h	9%
SPM	106.59	g/h	7.79	g/h	9%
CO_2	168,288.27	g/h	12,292.09	g/h	9%
N_2O	2.87	g/h	0.21	g/h	9%
CH_4	4.06	g/h	0.30	g/h	6%

The comparison with the UCC Scenario is reported in terms of percentage reduction.

3.2.4. Pessimistic Scenario

The Pessimistic Scenario uses traditional vehicles to deliver the goods from the UCC (zone 2) to city centre (access point *d*). The assumption on the consolidation load of 20%, implies that on the average 91.36 vehicles leave the UCC towards the city centre (the number of vehicles increases of 49.9%). In this Scenario the number of vehicles increases due to a worse consolidation load. Fuel consumption and emissions for this scenario are due to the diesel trucks (see Table 8).

Table 8: Pessimistic Scenario

Pessimistic Scenario					
	Zone 1-8		Zone 1		Increase
Fuel Consumption	83,974.62	g/h	7,713.63	g/h	80%
NO_x	1,567.45	g/h	143.98	g/h	80%
CO	1,033.20	g/h	94.91	g/h	80%
PM10	147.69	g/h	13.57	g/h	80%
SPM	167.11	g/h	15.35	g/h	80%
CO_2	263,821.96	g/h	24,233.80	g/h	80%

3.3. Annual Savings

The fuel consumptions and the emissions for several scenarios are compared.
Tables 9-12 show the annual savings that are achieved with the scenario considered (Electric, Optimistic, Intermediate and Pessimistic) compared to UCC Scenario.
First, the whole day emissions are calculated by multiplying the peak hour' results by a factor of 11.
Then the number of working days per year is assumed according to the following cases:

- I: 288 working days per year
- II: 264 working days per year
- III: 240 working days per year

The whole day results are multiplied per the working days per year to get the annual fuel consumptions and emissions of the different scenarios.
To obtain the annual savings achieved through the Electric Scenario, Optimistic Scenario, Pessimistic Scenario, and Intermediate Scenario, their annual values are compared with the annual values of UCC Scenario.
Table 9 shows the very high savings achieved with the Electric Scenario due to the large use of electric vehicles.

Table 9: Annual Saving with Electric Scenario

	Annual Savings (Electric Scenario)		
	I [ton]	II [ton]	III [ton]
Fuel Consumption	9.1855	8.4201	7.6546
NO_x	0.1715	0.1572	0.1429
CO	0.1130	0.1036	0.0941
PM10	0.0162	0.0148	0.0135
SPM	0.0183	0.0168	0.0153
CO_2	28.8580	26.4531	24.0483
N_2O	0.0005	0.0005	0.0004
CH_4	0.0007	0.0006	0.0006

Table 10 shows the high savings achieved with the Optimistic Scenario due to the high level of cargo consolidation (80%).

Table 10: Annual Saving with Optimistic Scenario

	Annual Savings (Optimistic Scenario)		
	I [ton]	II [ton]	III [ton]
Fuel Consumption	4.1665	3.8193	3.4721
NO_x	0.0778	0.0713	0.0648
CO	0.0513	0.0470	0.0427

PM10	0.0073	0.0067	0.0061
SPM	0.0083	0.0076	0.0069
CO_2	13.0898	11.9990	10.9082
N_2O	0.0002	0.0002	0.0002
CH_4	0.0003	0.0003	0.0002

Table 11 shows the good savings achieved with the Intermediate Scenario due to the slightly better cargo consolidation (50%).

Table 11: Annual Saving with Intermediate Scenario

	Annual Savings (Intermediate Scenario)		
	I [ton]	II [ton]	III [ton]
Fuel Consumption	1.1577	1.0612	0.9647
NO_x	0.0216	0.0198	0.0180
CO	0.0142	0.0130	0.0119
PM10	0.0020	0.0019	0.0017
SPM	0.0023	0.0021	0.0019
CO_2	3.6371	3.3340	3.0309
N_2O	0.0001	0.0001	0.0001
CH_4	0.0001	0.0001	0.0001

Table 12 shows the increase of emissions and fuel consumption with the Pessimistic Scenario due to the worse cargo consolidation (20%).

Table 12: Annual Saving with Pessimistic Scenario

	Annual Savings (Pessimistic Scenario)		
	I [ton]	II [ton]	III [ton]
Fuel Consumption	-10.884	-9.977	-9.070
NO_x	-0.203	-0.186	-0.169
CO	-0.134	-0.123	-0.112
PM10	-0.019	-0.018	-0.016
SPM	-0.022	-0.020	-0.018
CO_2	-34.194	-31.345	-28.495
N_2O	-0.001	-0.001	-0.001
CH_4	-0.001	-0.001	-0.001

4. CONCLUSIONS

In the paper an UCC for a medium Italian city is analyzed via simulation.

Simulated scenarios show the environmental benefits of the UCC: lower number of vehicles and a lower quantity of emissions thanks to a better load consolidation.

The success of UCC depends on the percentage of load consolidation that it is possible to reach. In the Optimistic Scenario, for instance, emissions reductions are around 30% as shown in Table 6. While in the Pessimistic Scenario, the environmental emissions increase respect the base UCC Scenario.

It could be interesting to simulate also several policies (Congestion Charging, Weight Restrictions and Time Restrictions) to evaluate their impact on the UCC use. To do this it would be necessary to model and validate the behavior of UCC users (transporters and retailers). On the economic point of view, the UCCs can be viable only in the Optimistic Scenario, otherwise they need some public supports.

In future studies it could be interesting to make online measurements of traffic level within the city by using connectivity. In this manner it could be possible to implement more feasible policies to regulate the freight traffic within the city. Simulation could support such studies on how to optimize online the traffic and the freight distribution.

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