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A methodology to design and assess scenarios within SULPs: the case of Bologna

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Abstract

The paper, focusing on the importance to develop sustainable urban logistics plan (SULP) and to implement a demand model system for the assessment of future scenarios, presents a methodology for setting up a SULP modelling, using different sources of data (i.e. automatic traffic counts, floating car data, surveys with retailers and transport operators). The methodology is applied to the functional urban area (FUA) of Bologna (Italy). In particular, it was used for assessing the new city logistics scenarios of the Bologna's SULP where a set of measures have been proposed for improving city sustainability and livability.

Keywords: city logistics; urban freight plan; sustainable urban logistics

1. Introduction

Although urban freight transport (UFT) plays an essential role to satisfy the economic and livability needs of citizens, it is characterized by negative economic, environmental and social effects like congestions, air and noise pollution, and safety (Cui et al., 2015; Campagna et al., 2017). In order to tackle the problems above in city planning, the European Commission (EC) promoted the concept of sustainable urban mobility, and published guidelines to develop and implement sustainable urban mobility plans (SUMP, 2013). In addition, the project ENCLOSE (Energy

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Efficiency in city logistics services for small and mid-sized European historic towns; Ambrosino et al., 2015) defined guidelines for SULPs.

Importantly, sustainable development objectives can be pursued by means of measures that are sometimes conflicting and generate impacts that depend on the acceptance of stakeholders, as well on external factors (Lindholm, 2013; Stathopoulos et al., 2012; Le Pira et al., 2017). Thus, the first objective of the paper is to point out, from the literature on urban freight transport planning, the relevance to develop sustainable urban logistics plans and to identify a comprehensive and efficient procedure to do it (Section 2).

Within this procedure, it is fundamental to consider that, following Nuzzolo and Comi (2014a), city logistics measures can be used as elements of the planning procedure by providing specific solutions in the definition of intervention scenarios. Therefore, to implement the most effective city logistics measures, the choice of a set of measures should be based on a design scenario implementation process, which consists of several steps as recalled in Section 3. Consequently, the second objective of the paper is to propose a methodology for the assessment of city logistics scenarios, which uses different sources of data (i.e. automatic traffic counts, floating car data, surveys with retailers and transport operators; Comi et al., 2018) for setting the demand model system (Section 4).

Finally, the goodness and the opportunities offered in using such a methodology is explored through a real test case, i.e. the application to the metropolitan area of Bologna (Italy) elaborated in the context of the SULPiTER (*Sustainable Urban Logistics PlannIng To Enhance Regional freight transport*; Rubini and Lazzari, 2018) project.

The paper is organized as follows. Section 2 reviews the current state-of-the-art on city logistics planning, while Section 3 presents the methodology developed. Then, Section 4 deals with its application to the metropolitan area of Bologna, and Section 5 draws conclusions and further research road ahead.

2. City Logistics planning

Although there is a growing interest towards freight mobility from local administration point of view, only large cities as Barcelona, London, Paris, Rome from some years included freight mobility within their urban transport plans (Holguin-Veras et al., 2015; Nuzzolo et al., 2016; Russo et al., 2016). The small and medium-size cities faced with difficulties in addressing urban logistics due to the ex-ante adversity of operators (both retail outlet owners and transport and logistics operators) and the wellness to keep city alive. These difficulties, together with few knowledge on this segment of mobility and the lack of capability of planning integrated solutions (not only for city logistics), of managing process evolution and insufficient structure and skills at the level of the single municipality, restrained to start the new era of planning (Russo and Comi, 2018; Musolino et al., 2019). In fact, as demonstrated by the large literature (Russo and Comi, 2016 and 2017 and references quoted therein) the improving of city sustainability and livability cannot be reach neglecting freight contribution.

Besides, as introduced above, to solve the relevant lack of sustainability goals in city planning, the EC has promoted the concept of sustainable urban mobility and has supported guidelines for developing sustainable urban mobility plans (SUMP, 2013) and foresaw the involvement of small and mid-sized European historic towns (Ambrosino et al., 2015; SULP, 2016). In addition to the work carried out by ENCLOSE, the EU funded project SULPiTER (Interreg Central Europe, 2016-2019), which is facing the development of SULPs in several European cities, focusing on wider areas named functional urban areas (FUAs; OECD, 2013). Specifically, SULPiTER aims to support cities to improve their understanding of FUA freight-related phenomena, according to an energy and environmental perspective, enhancing their capacity in urban freight mobility planning to efficiently develop and adopt SULPs. The FUAs involved in the project are the following medium cities: Bologna, Brescia, Budapest, Maribor, Poznan, Stuttgart and Rijeka. Therefore, SULPiTER designed and developed a tool for supporting policy makers and the process of elaboration of alternative city logistics scenarios. The tool provides a deep understanding of the urban freight distribution in each FUA and includes a modelling system to feed the evaluation through performance indicators. Below the methodology developed and implemented is described with its application to a real test case.

3. The proposed methodology

Since the characteristics of urban areas can substantially differ, while all measures could produce good results in terms of external transport costs, some of them could, for example, increase the costs incurred by freight system actors. Therefore, to implement the most effective city logistics measures, the choice of a set of measures should be based on a design scenario implementation process, which consists of several steps (Fig. 1) able to:

- reveal the current critical issues through specific surveys (e.g. traffic counts, interviews with retailers, truck drivers etc.; *data collecting*; *critical issues*);
- define models to simulate the current scenario and assess the future (*models*);
- share objectives and find an optimal compromise among the different actors involved (*stakeholder consultation*);
- assess ex ante the *new scenario* by estimating impacts and system performances, and compare them with a set of given target values (*ex-ante assessment*);
- monitor the freight system after *scenario implementation* (ex-post) in order to evaluate the effectiveness of implemented solutions.
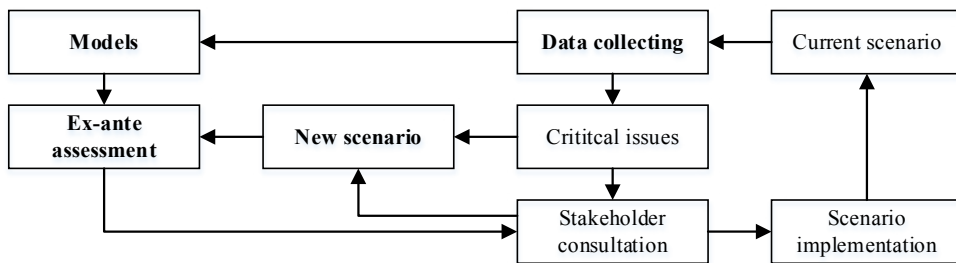

Fig. 1. The proposed scenario assessment procedure

3.1. Data collecting

In the proposed methodology, data become relevant because they allow to identify the current critical issues and to setting up the simulation models. Usually, the high costs to obtain such information strongly condition such activities. Nowadays, the new opportunity offered by telematics can come in help. A range of vehicle movement data can now be automatically collected from low cost sensors that are able to assist the improvement of the distribution system understanding and the increase of their efficiency (Taniguchi et al., 2016). Vehicle monitoring technologies that have the potential to charge both passenger and goods vehicles for using the road system, allow a new array of pricing schemes to be introduced. Indeed, the surveys with actors of goods movements remain important for investigating decision making, with consequence to push researchers to investigate methodology for their integration.

3.2. New scenario

Measures implemented to achieve sustainability objectives are sometimes conflicting and depend on the acceptance of involved stakeholders (Gatta and Marcucci, 2014). It is important to stress that a participative process involving stakeholders, e.g. using a freight quality partnership (Allen at al., 2010; Balm et al., 2014), is essential to the success of the initiative by supporting all the work phases. Based on a large investigation of urban freight transport within the identified FUA through different sources of data (Gatta et al., 2017), the different supply-chains in relation to the characteristics of goods moved and of delivering process can be identified as shown below for Bologna (Italy). Besides, according to the discovered critical issues of each distribution process, some city logistics solutions can be proposed.

3.3. Models

In the above procedure, a key role is played by goods demand models that should allow us to obtain the different goods flows, considering the factors that generate them, and help to identify a set of measures to be implemented for achieving sustainability goals.

The modelling framework used, derived from the current literature and is based on that proposed by Nuzzolo and Comi (2014b), which allows to simulate the restocking through model sub-systems. Starting from the quantity attracted by each traffic zone, it allows us to estimate the quantity, delivery and vehicle origin-destination (O-D) matrices characterized by freight types, transport service types and types of vehicle used.

Therefore, model system allows us to estimate: the average daily quantity O-D matrices by freight types, the average delivery O-D matrices by transport service type (e.g. on own account or by third party) and the average vehicle O-D matrices by delivery tour departure time and vehicle type.

The global demand function can be decomposed into the product of partial share sub-models, each relating to one or more choice dimensions. The sequence used is the following:

- quantity O-D matrices

$$Q_{od}[s] = Q_{d.}[s] \cdot p[o/ds] \qquad (1)$$

where $Q_{od}[s]$ is the average daily quantity of freight type s moved between the origin o and the destination d; $Q_{d.}[s]$ is the average daily quantity of freight type s attracted (required) by economic activities located in zone d, obtained by an *attraction model*; $p[o/ds]$ is the probability that freight attracted by zone d comes from zone o (e.g. warehouse location zone); it represents the acquisition share obtained by a discrete choice *acquisition model*;

- delivery O-D matrices

$$ND_{od}[r,s] = Q_{od}[s]/q[r,s] \cdot p[r/s] \qquad (2)$$

where $ND_{od}[r,s]$ is the number of deliveries of freight type s performed by transport service type r on pair od; $p[r/s]$ is the probability of being restocked by transport service type r obtained by a discrete choice *transport service type model*; $q[r,s]$ is the average daily quantity of freight type s moved by transport service type r.

- delivery O-D matrices

$$VC_{od}[v,r,s] = ND_{od}[r,s]/nd[r,s] \cdot p[v/odrs] \qquad (3)$$

where $VC_{od}[v,r,s]$ is the number of vehicle of type v that delivers freight type s by transport service type r on pair od; $nd[r,s]$ is the average number of deliveries performed by delivery tours operating on od pair; $p[v/odrs]$ is the probability that deliveries are performed by vehicle type v obtained by a discrete choice *vehicle type model*.

3.4. Ex-ante assessment

For scenario assessment, a multi-criteria decision analysis (MCDA) tool called logistics sustainability index *(LSI)* was proposed. This index allows transforming MCDA to a multi-stakeholder tool able to include the different perspectives of the stakeholders in the evaluation process. The LSI represents an integrated evaluation tool able to quantify the overall performance of a logistics system according to different criteria and different perspectives. It is elaborated adopting a bottom-up approach which starts from the valorization of basic performance indicators that will be aggregated into weighted composite indicators per impact area (i.e. economy and energy, environment, transport and mobility, society, policy and measure maturity, social acceptance, user uptake; Nathanail et al., 2016) and finally into a unique synthetic index. The LSI may thus evaluate one or more impact areas jointly, and becomes useful when a comparison between the current status and a potential scenario is required, or when two potential scenarios have to be compared. Given an impact area i (e.g. energy consumption, pollutant emission), the LSI_i is computed as follows:

$$LSI_i = \sum_m I_m w_m \qquad (4)$$

where I_m is the normalized value of indicators m with a minus or plus sign, according to its contribution to the sustainability (i.e. positive if benefit, negative if costs); w_m is the weight given to the impact area indicator/metric m which can be estimated for example using a Delphi approach (Cascetta, 2001).

4. Bologna case study

The present case study provides an example of application of the methodology presented above. The SULP developed by Metropolitan City of Bologna is one of the ten strategic lines of SUMP (Sustainable Urban Mobility Plan), which is, in fact, a sectoral plan for the organization of the urban distribution of goods, the transport of goods and related logistics activities and infrastructures.
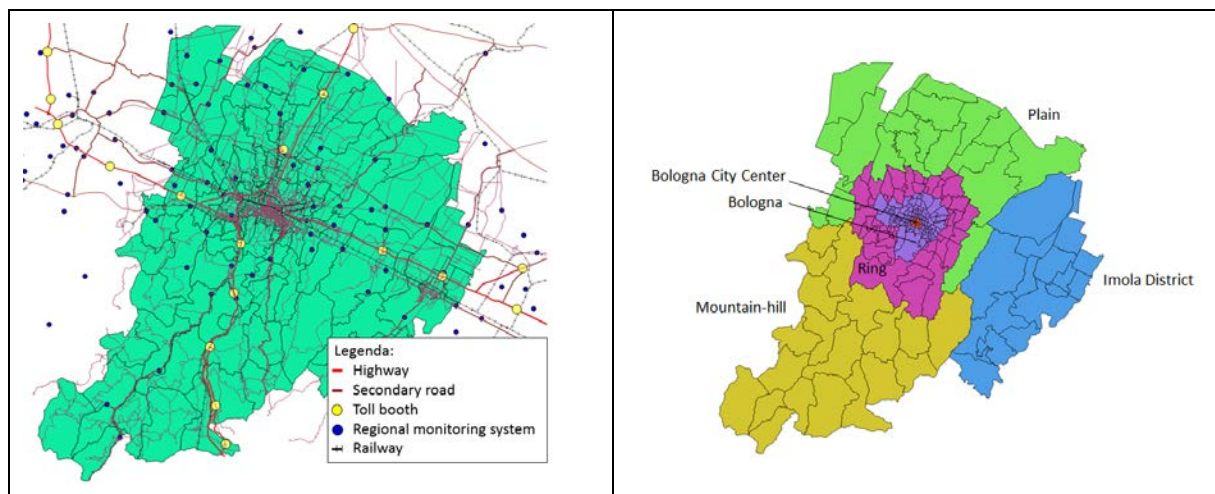

Fig. 2. The study area

4.1. Data collecting

In 2018, the municipal authorities within the European project SULPiTER (Comi et al., 2018) commissioned a survey, which was carried out by academic researchers with a twofold aim. One was to evaluate the current stages of freight transport within the municipality and the other to develop a modelling framework able to support the ex-ante assessment of future scenarios. Below, for the sake of readability, the main results of surveys will be summarized. For more details, refer to Comi et al. (2018) and Campagna et al. (2018).

The study area is of about 3,702 km², with about 1,009,828 inhabitants and 86,000 employees related to trade. It involves fifty-five municipalities and is composed of 261 zones corresponding to the census area. These zones were used to draw all the statistical data available (population, enterprises, employees), and have been then aggregated into six macro-zones for the purpose of the elaboration of the SULP: Bologna City Center, Bologna, Ring (conurbation of Bologna), Plain, Mountain-Hill and Imola district (Fig. 2).

The surveys consisted of:

- automated traffic counts of commercial and other vehicles at the border of Bologna LTZ and in the monitoring stations of the regional system;

- about 25 interviews of transport and logistics operators in order to investigate the supply chain of freight distribution within the study area;
- about 1,200 interviews of retailers in order to investigate the retail trade in the study area for each freight type;
- about 500 interviews of manufacturers in order to investigate the industrial trade in the study area.

The study area is a mixed land-use area (CBD, residential, commercial, tourist and warehousing) interested by about 37,000 tons for days. In terms of freight segmentation, 32% consists of freight destined to retailers, 7% to food-and-drink outlets, 1% to hotels, 3% to automotive, while the remaining 57% to warehouses. Some critical issues emerged and are listed below:

- 78.5% of the vehicles used to delivery/self-sufficiency activities are light duty vehicles (car and van) in other words more vehicles are necessary to deliver the goods for a fixed volume of them;
- most of the vehicles are diesel and petrol (79.1%); unwillingness to use eco-friendly vehicles (liquefied natural gas:12.9%, methane: 6.0%, electric: 1.2% and hybrid: 0.8%);
- only 1% of the industrial companies use railway mode to transport the goods;
- difficulties to use loading bays.

4.2. New scenario: scenario definition

According to the objective of the SULP (i.e. to pursue, in the medium-long term, several actions capable of responding on the one hand to the needs and demands of freight transport, maintaining a high levels of service, and on the other hand to reduce, progressively, CO_2 emissions and other negative externalities, by ensuring environmental, economic and social sustainability, and taking the critical stages identified into consideration), a consultation forum with FUA stakeholders were carried out and the following city logistics measures were proposed and the future scenario was thus defined:

- urban consolidation centers: they act as hubs, allowing the goods to be concentrated in one place (with large goods vehicles) before the distribution in the cities;
- limited traffic zones (LTZ): the rules of access to limited traffic zones must guarantee the satisfaction of the needs of the urban area (e.g. environmental) without blocking the goods distribution (possible rules are time windows for circulation, access allowed only to some class of vehicles and so on);
- proximity logistics spaces: they constitute an alternative for those who cannot complain with the tight constraints of the LTZ, guaranteeing deliveries with means adequate to pedestrian zones (e.g. cargo-bike) or with other means (e.g. hand trolleys);
- delivery points: they reduce routing complexity and increase e-commerce requirements;
- dynamic parking lots: they optimize the land use considering all the requirements of the different involved subjects. They go on with other measures to concentrate loading/unloading operations;
- night-time deliveries: the aim is to reduce the interaction between freight vehicles and the other traffic components (that during the night are less than respect to a typical day) and to make available the goods at the opening, constraints can be the noise and the higher costs;
- multi-modal distribution: this strategy implies the use the railway up to an urban distribution center and then the road transport for urban goods distribution, this solution can reduce pollutant emissions and support the policies of goods consolidation;
- permanent freight quality partnership (FQP): FQP are essentially "local forum" with the aim to bring together the freight transport and logistics stakeholders of public and private sectors to discuss problems and identify and implement solutions.

4.3. Models: demand modelling calibration

The calibration of the modelling system presented in the earlier section was performed through data coming from interviews with retailers and transport operators as well as from automatic traffic counts on several roads within the metropolitan area of Bologna.

The sub-systems presented in Section 3 were thus specified and calibrated. The modelling system was specified through easy-to-capture variables (especially for its forecasting use) represented by level-of-service attributes and

aggregate socio-economic variables, such as number of employees. The models are the result of several specifications and calibrations based on different combinations of possible attributes. Models were calibrated combining disaggregate (i.e. from interviews) and aggregate (from automated traffic counts) data using generalized least squares (GLS) estimators in relation to the availability of data and to their statistical reliability. On the basis of traffic counts, the vehicle O-D flows were obtained ($\hat{V}C_{od}[v,r,s]$), while on the basis of interviews, the model parameters were estimated. Then, the parameters of models were updated by solving the following expression:

$$\min_{\beta} VC = \sum_{odvrs} \left[VC_{od}[v,r,s] - \hat{V}C_{od}[v,r,s] \right]^2 \qquad (5)$$

Fig. 3 reports a comparison between vehicle O-D flows obtained implementing the models described at earlier section and those obtained implementing an aggregate procedure for estimating O-D demand flows using traffic counts (Cascetta, 2001). The mean square error (MSE) is 1014 while the root mean square error (RMSE) is 1643. The estimates O-D vehicle flows are slightly scattered. However, further analyses are in progress to verify the dispersion of estimates, including other socio-economic data (different than number of employees) in the models.
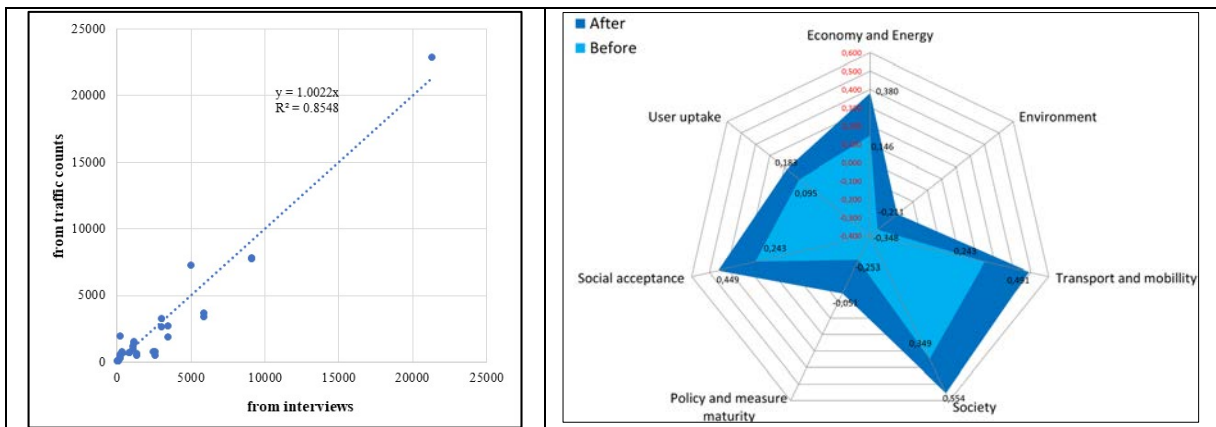

Fig. 3 – Left: Revealed (from traffic counts) *vs* Estimated (from interviews) vehicle O-D flows [veh/day]; Right: LSI results with before/after comparison

4.4. Ex-ante assessment

Once, the future scenario was defined, the developed modelling framework was used for its assessment. The LSI was calculated according to the seven impact areas defined by Nathanail et al. (2016) and the results are plotted in Fig. 3 (right), which compares the LSI computed for status quo and future scenario. The improvement in the different impact area can be thus evaluated thanks to the implementation of the set of measures described earlier.

5. Conclusions

Today, most cities have to deal with the challenges to promote a sustainable and livability city, and different set of city logistics measures can be implemented. To pursue such a goal, EU promotes the development and implementation of SULP. In the paper, a methodology for designing and assessing scenarios within the SULP has been proposed.

The methodology was applied to the FUA of Bologna where problems of sustainability protection are particularly urgent, and useful indications in terms of policy making could be derived. The methodology proposed could be further developed in the near future with an agent-based simulation which could allow to focus on the integration among actors. Finally, further analysis are in progress for improving the demand models including other socio-economic attributes.

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