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A review of methodologies to assess urban freight initiatives

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Abstract: Only few urban freight initiatives are expanding their scale of application beyond the initial pilot experimentation. To overcome existing barriers to larger scale optimization of urban freight distribution activities, it is necessary to develop and test proper methodologies that assess all aspects relevant to this context. In this paper we propose a classification of existing assessment methodologies, in order to underline their advantages and disadvantages, along with possible research gaps and future trends. For this review we adopt a framework constructed on two dimensions of an assessment methodology, namely method used and scope. As for the method used, methodologies can be either quantitative, if they aim at simulating or evaluating the outcomes in terms of vehicle flows, pollutant emissions, or monetary outcomes, or qualitative, if they are directed towards elucidating the subjective assessment of stakeholders. Concerning the scope, existing methodologies can cover three main aspects of urban freight distribution systems, such as measures to be assessed, stakeholders and impact areas.

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Keywords: Urban freight; assessment method; literature review; future trends; stakeholders

1. INTRODUCTION

Urban freight activities are one of the most complex and impacting ones within a supply chain, since logistics service providers and carriers needs to be more responsive to the needs and expectations of businesses and consumers, who require the delivery of goods on demand (Holguín-Veras and Thorson, 2003). On the other side, urban freight activities account for 14% of vehicle-kilometres, 19% of energy use, and 21% of CO2 emissions (Schoemaker et al., 2006), beyond generating other negative spill overs such as nuisance and traffic congestion (Taniguchi and Van der Heijden, 2000). In this context, both operations efficiency and environmental benefits should be achieved together. To this end, a combination of private initiatives and public policies is required for developing sustainable urban freight systems (Anderson et al. 2005).

Nevertheless, in recent years several initiatives in urban freight context proved to be successful in achieving the objectives set by all stakeholders involved, and have emerged as a response to the negative impacts generated by freight transportation demand in urban areas. However, only few of these projects are expanding their scale of application beyond the initial pilot experimentation, and many others failed because of several reasons, such as divergent objectives between the stakeholders or low profitability (Gammelgaard, 2015). Moreover, these initiatives generate impacts that are influenced by the acceptance of stakeholders and external factors (Russo and Comi, 2011).

It is be argued here that overcoming existing barriers to larger scale optimization of urban freight distribution activities requires properly developed and tested methodologies. Such methodologies should assess all aspects relevant to this context and aim at measuring and fostering long-term sustainability of urban freight distribution, both operational and economical (Balm et al. 2014).

Our aim is to review existing methodologies to underline the advantages and disadvantages of these methodologies, along with possible research gaps. Some reviews already exist in the field of City Logistics (hereafter we will refer to City Logistics and urban freight as synonyms), such as the general reference taxonomy of CL based on 92 papers proposed by Wolpert and Reuter (2012). On the other hand, more specific reviews on assessment methods are proposed by Ambrosini and Routhier (2004), who studied objectives, methods and results of surveys carried out in this field, and Anand et al. (2012b), who provided a review of existing modelling efforts in city logistics. In this paper we propose a different perspective on the classification of existing literature, by looking at how different assessment methodologies take into consideration and evaluate several aspects of the multi-faceted topic that is City Logistics. Furthermore, we intend to identify future trends in the assessment of urban freight initiatives. The paper is structured as follows: in Section 2 the review framework is presented. Then, the methodologies reviewed are presented in terms of their method in section 3, and their scope in section 4. Finally, discussions and conclusions are drawn in section 5.

2. REVIEW FRAMEWORK

Since the interest on urban freight distribution is recent, we propose a review on works spanning from 1999 to present

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days. We searched the main databases of scientific refereed journals, such as Google Scholar, Science Direct, SpringerLink or Scopus, as well as the public documents from the main European projects in urban freight distribution. We initially searched for field specific key words (and their combination), such as "city logistics", "urban goods movement", "urban freight transport", "urban distribution", and "urban logistics". Then, we refined the initial set of works by selecting only those that present an evaluation framework, and assembled a total of 15 methodologies and 27 papers[1].

The tentative review of assessment methodologies presented in this paper is constructed on two dimensions, namely: the method used and the scope. In particular, we classify quantitative and qualitative methods. Quantitative methods make use of data retrieved from large-scale surveys or technical data to develop simulation model or scenario analysis. Qualitative approaches mainly comprise focus groups or interviews with stakeholders to identify decision-making criteria and evaluate possible alternatives or illustrate different point of views (Steckler et al. 1992). As for the scope, we argue that existing assessment methodologies cover the following aspects of urban freight distribution systems:

- *Measures*: a methodology can assess one of the measures applicable to the urban freight transport system (Anand et al., 2012a). Among them we find public measures, such as urban consolidation centre, road pricing or load factor control, and private measures, such as the introduction of automated pickup points (Quak et al., 2014)
- *Stakeholder:* an assessment methodology should take into account the objectives of most of the stakeholder of urban freight distribution systems, namely shippers, receivers, carriers, citizens and public authorities (Russo and Comi, 2011; Anand et al., 2012a)
- *Impact area:* we identify four impact areas from literature, namely environmental, economical, social and operational (Macharis et al., 2009; Patier and Browne, 2010).

3. METHOD

3.1 Quantitative methods

We define as *quantitative* those methods that aim at simulating or evaluating the outcomes of a freight distribution system, in terms of vehicle flows, commodity flows, pollutant emissions, and monetary outcomes. These methods require, in most of the cases, a significant amount of various data in order to be validated and generate robust results. Freight modeling techniques have been for several years the main focus of scientific works in the urban freight context. Ideally, freight demands models should build a strong behavioural foundation, incorporates freight and passenger interactions and should be capable of handling policy changes (Giuliano et al., 2010). In particular, the last attribute is of paramount importance in urban contexts, in reason of the aforementioned issues generated by the freight activities. Anand et al. (2012b) state that efficiency is one of the most investigated aspects by city logistics modelers. Modelling approaches focus mainly on traffic flow and freight flows, as well as land use and location. Most of urban freight models are derived from more consolidated passenger flows models. For instance, the traditional four-step approach, which comprise trip generation, trip distribution, mode choice (often omitted) and traffic assignment (Hosoya et al. 2003), has been adopted by Muñuzuri et al. (2010) to simulate traffic flows in the city of Seville at peak hours, taking into account replenishment deliveries to local retailers and home deliveries. A strong assumption has been made that none of the trips made are multi-stop trips, since the authors only simulated flows in a narrow window of time. A further development by the same authors (Muñuzuri et al., 2011) relaxed this assumption, introducing multi-stop routes, on the basis of retailers' location and the average distance traveled between stops. However, as Hunt and Stefan (2007) noted, the four-step approach still overlooks the strong tour-based nature of urban commercial flows. These authors adopted a tour-based model for simulating own account urban commercial flows, including service trips. This type of modeling approach is more detailed in the sense that it considers several features of the delivery trip, such as the purpose of the tour, the specific tour start time, and the characteristics of the stops on the tour (Nuzzolo et al., 2011). This level of detail of course is seen as an advantage of this approach, but it is in turn time and data intensive. A possible solution is to implement an aggregate approach (Chow et al. 2010). For the tour definition, probabilistic approaches are adopted to generate the choice of the next destination stop and to make the decision of whether return to the base (warehouse) or not on each tour.

A branch of urban freight modeling that is gaining importance is represented by agent-based modeling, which might provide a feasible alternative to overcome the issue of stakeholders' interactions that is rarely taken into account in "traditional" traffic models. In agent-based modeling, each stakeholder can be modeled as an agent possessing objectives and decision-making attributes. Taniguchi and Tamagawa (2005) simulated traffic flows considering stakeholders' behaviors and objectives, adopting a genetic heuristic algorithm to model the vehicle routing problem (VRP) of minimizing cost with constraints. In Wisetjindawat et al. (2005), the stakeholders, namely retailers, wholesalers, manufacturers, suppliers, and carriers, interact with each other within an urban supply chain through information and material flows. A combined approach agent-based with vehicle routing has been proposed by Van Duin et al. (2012) and Teo et al. (2012). Agent-based modeling shows great potential for capturing the changing distribution patterns in response to urban freight initiatives, with significantly less data required for the simulation. However, different interactions between agents have to be modeled according to the initiative that is the focus of the evaluation process (Knaak et al. 2006).

[1] This is a refinement to the review proposed by Danielis et al. (2015), who mainly reviewed mostly the proceedings from the 8th International Conference on City Logistics that was held in Tenerife on 17-19 June 2013

Comprehensive methodologies that integrate the freight flows simulation with policy identification and urban freight planning scenarios are also available in literature (Filippi et al., 2010). Some of the methods integrate qualitative aspects in a quantitative assessment framework. Social cost-benefit analysis (SCBA) is an extension of the traditional CBA used for transport projects appraisal, that includes non-market effects of decisions. SCBA methodology has been recently adopted for the STRAIGHTSOL project (Balm et al. 2014). SCBA aims at giving a quantitative evaluation of all stakeholders' objectives, but several assumptions have to be made for treating non-quantifiable effects in the quantitative evaluation of the monetary value of the project.

3.2 Qualitative methods

Surveys are a suitable option for assessing stakeholders' responses to freight policies (see Allen et al., 2012 for a review on surveys on urban freight transport). Anderson et al. (2005) developed an evaluation framework composed of an assessment approach, aiming at defining the companies' response to policy measures through interviews, and a set of indicators retrieved from survey data. The evaluation is performed as a comparison between the actual scenario and the scenario constructed by applying the companies' responses to existing data depicting the actual operations. The selection of the policy measures is also part of the methodology, since changes in operations are directly assessed with the companies involved.

Multi-criteria multi-stakeholders evaluation method (MAMCA) developed by Macharis et al. (2009), has been emerging as a comprehensive tool for ex-ante evaluation of CL measures. Through this methodology it is possible to identify the objectives of the different stakeholders involved and translate them into weighted criteria. Quantitative and qualitative key performance indicators (KPI) are then assigned to each criterion, allowing evaluating each alternative with regards to a given criterion. As mentioned before, stakeholders have a large impact on the implementation of a project, and therefore including them in the decision making process can be a crucial element in the successful implementation of the measure. Other multi-criteria methods, such as Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP), are used in the first place to define the objectives of CL planning, and in second place to evaluate alternatives. These methods involve different stakeholders in the evaluation process, but in a less explicit way than what happens with the MAMCA approach. Awasthi and Chahuan (2012) integrated these two goals adopting a combined approach with AHP for defining the objectives of CL planning and a TOPSIS algorithm for evaluating different scenarios against criteria highlighted with the AHP. The TOPSIS method is a technique for ranking alternatives by the level of similarity to an ideal solution, which maximizes the benefit criteria and minimizes the cost criteria. The AHP method do not allow for a dynamic modeling of the environment, since the elements that compose it are uncorrelated and influenced by a hierarchical structure (Meade and Sarkis, 1998). In response to this problem, the Analytical Network Process might represent a solution, since it depicts the dynamic relationships between decision attributes. However, we could find only one development of ANP in urban freight context, namely by Kaszubowski (2012). This is probably due to the complex framework that requires identifying several criteria and explicitly depicting their relationships.

Finally, there exist some methods that are based on purely subjective evaluation by a panel of experts or selected stakeholders. These methods are mostly used to assess the transferability of innovation and best practices. Business model analysis (BMA) is a qualitative methodology developed in management research, showing a potential for investigating the feasibility of urban freight initiatives from a business-oriented perspective. BMA has been recently adopted to assess different urban freight initiatives within the STRAIGHTSOL assessment framework (STRAIGHTSOL, 2014). Patier and Browne (2010) developed a set of indicators pertaining to Economy, Social, Environmental and Logistics domains of the CL, and ranked the innovations based on a qualitative assessment given for each indicator on a three grade scale (0,1,2). Evaluation is based on a comparison between achieved results and target goals. This leaves questions over the level to which these goals are set and if this influences the evaluation. The methodology developed for the BESTFACT project comprises a multi-criteria assessment along four categories: innovation and feasibility, magnitude of impacts, information accessibility, and transferability. Each criterion is evaluated using a scoring system between 0 and 3, by three experts independently, and an average value is given to each innovation. In essence, these approaches show some relevance in terms of involving the stakeholders from the selection of the best policy measure to be adopted. However, they show some issues when treating quantitative information in the evaluation.

4. SCOPE

An assessment method can have a broader or more narrow scope, in terms of measures that it intends to assess, number and type of stakeholders included in the assessment process, and the category of potential impacts measured.

4.1 Measures

In this sense, it is necessary to point out that the analysis of the scope cannot be performed without mentioning that the two types of method highlighted, namely quantitative and qualitative, do not share the same underlying main objective. In fact, on the one hand most of the simulation models (*quantitative* methods) provide a general, modeling framework for simulating traffic flows by calibrating the parameters of the model according to the measure that is being evaluated (although information needed from stakeholders for calibrating the model could vary slightly according to the type of measures investigated). On the other hand, semi-quantitative and qualitative methods explicitly include the measure in the evaluation process, hence committing the whole process to that specific measure.

As a matter of fact, modeling techniques mostly investigate measures that intervene on organizational aspects of supply chains, such as consolidation and cooperation schemes (Boerkamps and van Binsbergen, 1999; Muñuzuri et al.,

2010), or on measures having an effect on the overall logistics costs, such as low emission zones and road pricing (Nuzzolo et al., 2011).

The following measures have been found in the reviewed papers:

Table 1 CL measures investigated

Measure	# of papers	Method
Consolidation and cooperation schemes, such as Urban Consolidation Centres (UCC) or Micro-consolidation centres	15	All except tour-based models and FREILOT
Electric vehicle introduction	3	BESTFACT, SMARTFUSION
Public policies, such as: – weight or load factor control; – road pricing schemes; – time windows; – low emission zones;	6	Tour-based and Four-step models; Agent based; AHP; Survey
ICT solutions, such as Delivery Booking Systems (DBS) or ITS systems	5	FREILOT; Social Cost Benefit and Business Model analysis; BESTFACT; MAMCA
Night-time deliveries	3	Social Cost Benefit and Business Model analysis; MAMCA

Regarding this table, it has to be clarified that the STRAIGHTSOL project included three methods reviewed (Business Model Analysis, MAMCA and SCBA) for assessing consolidation schemes, ICT solutions and night-time deliveries. Nonetheless, we reckon that the distribution of methods on the identified measures would not change significantly.

Consolidation schemes, mainly UCC, are by far the most investigated measure in urban freight literature. This is due to their great potential in bringing operational benefits to private stakeholders in terms of increase in inventory control (Browne et al. 2005), and to the environment as well, because goods are consolidated and therefore fewer vehicles are needed for urban deliveries (although this positive outcome is still debated by scholars).

Surprisingly, we found that public policies are mostly investigated through quantitative modeling, although an exception is represented by the AHP and ANP methods. The reason for this gap can be traced down to the very nature of most of qualitative and semi-quantitative methods: the alternatives are assessed in a subjective way by stakeholders, who are not able to fully grasp the extent of the impact of policy changes on the urban context. Another reason might be related to the current implementation of qualitative and semi-quantitative methods. These methods found their relevance for most of the recent large-scale European funded projects, which aimed at fostering knowledge sharing and involve all stakeholders in the process. As a consequence, the focus might have been towards solutions that provide real operational and economic benefits for private operators, as opposed to public policies that might only increase the complexity of urban freight distribution.

4.2 Stakeholders

The last remark points out a complete opposite stance on the stakeholders' involvement in the assessment process. Qualitative and semi-quantitative methods have emerged in the context of urban freight distribution in the last years when the issue of including stakeholders' behavior became more and more relevant. On the contrary, in the initial period of interest for city logistics the aim of scholars was directed towards freight modeling, since most of them came from transport modeling and operative research fields.

It comes with no surprise therefore that stakeholders are more taken into account in qualitative methods. As a matter of fact, only qualitative methods and three papers on agent-based models investigated a subset of at least four stakeholders among the most important ones of urban freight, namely shippers, receivers, carriers, citizens and public authorities. However, surveys and methods to assess innovation transferability only take into account carriers, and sometimes citizens (Quak et al., 2014) or employees (Patier and Browne, 2010). Instead, all quantitative methods reviewed considered only carriers, with the exception related to the introduction of receivers (Hunt and Stefan, 2005).

4.3 Impacts

Finally, four types of impacts are identified, namely Economical, Environmental, Social and a fourth one that represents the effect of the measures on the level of service and the productivity indicators. Different terms have been assigned to this last category of impacts, namely technical (Awasthi and Chahuan, 2012), transport (STRAIGHTSOL, 2014), logistics (Patier and Browne, 2010) or operational (Anderson et al. 2005).

Table 2 Impacts investigated by a selection of papers

Paper	Year	Method name	Impact area
Quantitative methods			
J.D. Hunt and K.J. Stefan	2007	Tour-based models	Operational
Nuzzolo et al.	2011		
Boerkamps and van Nisbergen	1999	Four-step model	Environmental (in terms of vehicle*kms travelled)
Hosoya et al.	2003		
Munuzuri et al.	2011		
Taniguchi and Tamagawa	2005	Agent based/Multi-agent	Economic Environmental Social Operational
Knaak et al.	2006		Economic Environmental
Pluvinet et al.	2012	FREILOT	Environmental
Balm et al.	2014	Social Cost benefit analysis	Economic Environmental Social Operational
Qualitative methods			
Anderson et al.	2005	Survey	Economical Environmental Operational
Filippi et al.	2010		Environmental

Macharis et al.	2009	MAMCA	Economic Environmental Social Operational
Patier and Browne	2010	Non defined	
Awasthi and Chahuan	2012	AHP and fuzzy TOPSIS	
Kaszubowski	2014	ANP	
Lagorio et al.	2015	Quality Function Deployment (QFD)	Economic Environmental
Quak et al.	2014	Business Model analysis	Economic
Balm et al.	2014	SMARTFUSION	Environmental
Leonardi et al.	2014	BESTFACT	Mostly qualitative

It is clear that qualitative methods cover a broader set of impacts than quantitative ones.

For each impact category several indicators can be identified. A broad review of urban freight indicators is out of scope of this paper. However, only by focusing on some papers that presented the most advanced development in this sense it is possible to get some insights on the variety of indicators and their use. Environmental indicators are represented by the reduction of CO2 and other pollutant emissions; operational indicators refer to, for instance, the level of service to customers, the number of stops, the number of deliveries, or the punctuality of pick up and delivery. Some papers provide a more detailed description of urban freight indicators. Patier and Browne (2010) identified 24 core indicators pertaining to 5 impact category: Economic indicators comprise investment costs, customers' satisfactions etc.; social indicators include working conditions and employment. Finally, The STRAIGHTSOL project covers all the main impacts with 31 indicators, such as cost per item or investment costs (Economic impact), employee satisfaction, attractiveness of urban environment or accessibility perceptions (Social and transport system impacts).

5. DISCUSSIONS AND CONCLUSIONS

This work intends not only to present a structured representation of the literature, but also to identify research gaps and future trends. Moreover, it aims at increasing the knowledge on the potentialities and drawbacks related to the process of assessing urban freight transport initiatives as a mean to achieve their long-term sustainability.

Findings show that some of the qualitative methodologies retrieved from the literature (e.g. Multi actor multi-criteria analysis (MAMCA) by Macharis (2009)) are able to effectively evaluate all stakeholders' objectives and decision-making criteria. However, these methodologies show less potential for estimating future trends and the effect of external changes on the system, since they are mainly developed for evaluating alternatives. Moreover, a potential weakness of these methods is related to the subjective evaluation of quantitative outcomes, which may potentially influence the ranking between different alternatives. On the other hand, quantitative models provide simulation frameworks for traffic flows and consumers' demand, and have more potential for the integration with changes in stakeholders' behaviors or the dynamic introduction in the system of new measures. However, simulation models usually need high quality of data for the development and validation.

Only some of the analyzed methodologies propose sets of performance indicators to evaluate the overall success of an initiative. Moreover, we have found that there are no clear indications to be found in the papers reviewed for integration within an ex-post evaluation framework of the indicators, which are mostly identified and categorized for the ex-ante scenario evaluation. We argue in this sense that a proper assessment methodology should make leverage on the indicators for the continuous monitoring of the performance of the measure implemented. However, a strong barrier hinders the development and use of such methodologies: the lack of detailed data available to public and private stakeholders.

Finally, the trend that has emerged in the reviewed literature shows that more efforts are put towards the involvement of all the stakeholders in the evaluation process, through methodologies such as agent-based modeling and MAMCA. As a matter of fact, after 2011 only three of the papers reviewed present a quantitative method, which is identified as the less stakeholder-oriented. This is considered as a shift from the initial development that mainly opted for transport system modeling and scenario simulations based on quantitative data retrieved from survey and other secondary sources data. Future development in urban freight assessment, such as the interactive MAMCA, city logistics living labs or agent based modeling for decision making, are currently deepening the debate on stakeholders' interaction and involvement.

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