Costs and benefits of railway urban logistics: a prospective social cost benefit analysis

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Abstract

This paper presents a general framework to assess urban rail logistics suitability via a socio-economic cost benefit analysis. Firstly, we propose an overview on the basic notions of CBA and SCBA. Secondly, we identify and present the main types of costs and benefits or railway urban logistics services and the related final delivery services using low emission road vehicles to serve customers where the rail systems cannot. Thirdly, as an example of application, we propose to assess a scenario of deployment of a freight tramway in Paris, in a possible configuration. The results show the potential of those approaches but also show that it is important to contextualize them and inform the different users about their real capacities.

Keywords: combined transport; urban logistics; evaluation; socio-economic cost benefit analysis; simulation

1. Introduction

It is more than 20 years that urban logistics is a formal subject of research (Gonzalez-Feliu et al., 2014) and since Ruske (1994), several authors propose urban logistics solutions, which are of different nature and have different effects, exploring different possibilities from theory to practice (Taniguchi et al., 2001; Taniguchi and Thompson, 2008; Macharis and Melo, 2011; Gonzalez-Feliu et al., 2014). Urban consolidation is one of the main subjects in conciliating research and practice issues, and several authors manifested the difficulties of making such solutions operational (Allen et al., 2012; Verlinde et al., 2012; Janjevic et al., 2013; Morana et al., 2014). Multimodal urban logistics has been seen an interesting alternative solution since the beginning of the structured research on the field (Taniguchi and Thompson, 1999), but it remains mainly conceptual. Indeed, as highlighted by Ardvidsson and Browne (2013), most experiences of rail-road urban logistics are nowadays stopped, and to the best of our knowledge it seems that fluvial urban logistics remains marginal or few studied in literature.

Railway urban logistics is appointed as difficult since traveled distances by urban freight railway services remain short (and certainly extremely lower than the minimum distance of combined transport stated by Nierat, 1997), but this idea has been reexamined with the last advances on short rail services' research (Marinov et al., 2011). However, since the principle of urban freight railway services are a declination of urban consolidation schemes (Gonzalez-Feliu, 2013), they seem difficulty viable without a financial and organizational support at the project construction phase. This support can be made by Cost-Benefit-Analyses (CBA), already used in infrastructure development projects (DG Regio, 2008). Those analysis, and mainly those that relate monetary costs with both monetary and non-monetary benefits (called socio-economic CBA), are rare in urban logistics, which explicates partially the difficulty of such systems to be deployed and transferred (Gonzalez-Feliu et al., 2014b). For those reasons, it seems important to propose an analysis framework to clarify both researchers and practitioners and incite them to develop such practices (usage of SCBA in urban logistics strategic planning, particularly in railway urban logistics) in their project developments.

The aim of this paper is to propose a SCBA-based analysis framework for strategic scenario assessment in the context of railway logistics project development. First, the paper makes an overview on the basic notions of CBA and SCBA. Second, it identifies and presents the main types of costs and benefits or railway urban logistics services. Third, an example of application (that of the freight tramway in Paris, an ongoing project) allows to illustrate the SCBA framework and its application. Finally, the paper concludes on the capacities and targets of SCBA as well as further possible developments of the present work.

2. Bases of Social Cost Benefit Analysis

Assessing and evaluating the suitability of urban logistics solutions is a popular subject (Russo and Comi, 2010; van Duin et al., 2010; Ambrosini et al., 2013; Gonzalez-Feliu et al., 2013). However, cost-benefit approaches are less spread than in other fields, like infrastructure development of public transport planning (Hayashi and Morisugi, 2000).

Since railway-based urban logistics includes a non-negligible infrastructural component, and can be implemented in synergy with public transport initiatives (tramway, metro, train services), it seems suitable for us to propose a cost-benefit analysis framework (CBA). However, since the main benefits (and some costs) are non-monetary ones, it is important to see it on the perspective of extended CBA, also called Social CBA (SCBA). In this section we present the methodological bases of SCBA and the main adaptation issues to our case (railway urban logistics).

Let's start by recalling the basis of a classic CBA. This method consists mainly on listing on one side all monetary costs (investment and operational), and on the other side all economic benefits; this is done year after year, for a given time horizon (Gonzalez-Feliu et al., 2014). This time horizon is in general set to 10 years for infrastructure or public transport projects (DG REGIO, 2008). Then, benefits are confronted to costs year by year to obtain a ratio of gains/losses at the end of each year of the given horizon, and their difference is updated using an update rate in order to take into account the money updating year after year. Since the value of money is not the same year after year, it is important to define an updating rate a, which allows comparing two quantities of money at two different periods. Taking the value of a quantity of money V_t at time t, and V_n the value of this quantity at horizon n, they are related by the following equation

$$V_t = V_n/(1+a)n$$

In a classical CBA, given a year t, we can estimate the net benefit NB_t in year t as follows:

$$NB_t = B_t - C_t$$

where C_t are the monetary costs of year t (both investment and operational) and B_t the economic benefits (revenues) made at year t. After that, the discounted net benefit DNB_t is calculated on the basis of update coefficient a, using the following relation:

$$NB_t = NB_t / (1+\alpha)^{t}$$

Where the update rate α is set to 4% (Hayashi and Morisugi, 2000).

Then, we estimate the Net Present Value (NPV_t):

$$NPV_t = NPV_{t-1} + NB_t$$

Finally, an Investment Return Rate (IRR) is calculated, in a 10-year horizon, using the following relation:

$$IRR = \frac{NPVn}{\sum_{t=0}^{n} C_t}$$

In a SCBA approach, the considered costs and benefits are not only economic values but also non-monetary costs and benefits, as for example the reduction of environmental footprints, social benefits but also non-monetary costs which are not always easy to identify and quantify. In SCBA, economic, environmental and social costs and benefits need to be quantified then a monetary value is associated to them. Then the method to obtain savings is the same. At horizon n, we estimate a Socio-Economic Return Rate (SERR) in the same way IRR was calculated, but using extended costs (i.e. economic, environmental and social costs).

3. Socio-economic costs and benefits of railway urban logistics

The main investment costs are related to infrastructure investments. The most important investment costs are associated to two main categories of infrastructures: linear infrastructures, i.e., the railway line itself, and nodal infrastructures, mainly terminals and loading and unloading bays. In both case it is important to distinguish between the case where one or more new infrastructures are required and the case where all infrastructures are existing, so an adaptation of such infrastructures is envisaged.

Moreover, an urban railway service is in general arriving to the city, but since the urban space is rare and expensive, final destinations (customers) will not be able to be equipped with terminals, so the railway city freight stations need to be connected to retailers via a road transport. This implies also the creation of a specific fleet of vehicles used to link each train/tram stop to the final delivery locations, mainly small, electric vehicles (Arvidsson and

Browne, 2013). The costs of buying or renting such vehicles need also to be included into the investment costs list of the urban freight railway system.

The main operational costs are related to the addition of ruptures of charge. If urban consolidation centers imply one rupture of charge, rail logistics needs at least two: the first at the consolidation terminal, and the second at city, near destination. That means the need of two approach transport to rail terminals. The first is done in general by shippers, usually with existing vehicles, on a feeder perspective (Gonzalez-Feliu et al., 2013); the second is usually done by a specific fleet, as said before (Delaître and de Barbeyrac, 2012).

Concerning benefits, such systems ask in general a fee to customers using it, related to the number of parcels/pallets or to the quantity of freight transported. Since refight railway services do a limited number of stops, we can consider, as for public transport, a pricing system organized in categories of prize, directly related to the zones of origin and destination.

Other monetary benefits can be observed and related to potential savings of shippers or transport carriers using the system, as for example savings related to the part of transport non-done because using the system.

Concerning non-monetary costs, we can observe that although railways can present several advantages at medium and long term horizons, in the period of construction of the railway, also negative impacts to the environment can be observed. Such impacts are not only imputed to pollution and noise of railway works, but also to the decrease of potential customers for retailing and service activities around works.

Non-monetary benefits are in general associated to the potential savings, mainly at environmental and social, but also at an economic level. The main environmental and social benefits are imputed to greenhouse gas emission, pollution and noise savings, but we can define other benefits related to the improvement of the global quality of life of a city (for example related to congestion) at the only condition that such benefits would be quantified. Moreover, time savings can also be quantified, as opposing to private car transport, the impacts of delivery times on total transport cost are known and very important in transport management (Gonzalez-Feliu et al., 2013).

4. An example of application: the Paris freight tramway service

In this section we will try to illustrate the estimation of different costs and benefits for a given example: that of the freight tramway project in Paris (France). This project has been developed by APUR under the recommendations of the Ile-de-France Region who made an important part of its Urban Mobility Plan to goods transport (APUR, 2014). Moreover, the French Strategic Analysis Council stated on the interests for the collectivity (i.e. all inhabitants and stakeholders within a city or urban area) of using tramway infrastructures to bring goods into the city centers (Conseil d’Analyse Stratégique, 2012).

The initial project was based on experimentation consisting on making running a freight tramway on an existing line in order to identify the main benefits of using tram to bring freight to the city (APUR, 2014). Such experience resulted on interesting conclusions; the most important seems that of using the tramway not to capillary delivering points in the city center but to bring freight from periphery to the main city. For this reason, a project consisting on defining a new railway branch to link the far periphery of Paris metropolitan area to the existing tramway network was created. From this idea, we propose to quantify costs and benefits of making this project.

For infrastructure investment costs, we start by defining the unitary costs of building the linear infrastructure. According to Li (2011), several sources estimate this cost allowing to estimate range between 1.15 and 3.50 M€ per kilometer. Those costs include project, construction and testing costs (including human force, technical knowledge and materials, among others). Making an average between all references given by Li (2011), we established an average cost of 22.5 M€/km. Since this cost includes (for public transport) the eventual stop points, we could think that those costs would be lower. In a first time, for the purpose of this paper, we will set this value to 20 M€/km[1], and include in this cost the different cross-docking points (that can be called city multimodal points). Concerning consolidation terminals, we can take costs from multimodal construction literature (Janic, 2007, Genevois and d'Aubreby, 2012). In our case, the hypothesis made is that the space is available in an existing terminal and such costs will be related to a rental prize than a construction cost to pay once. We estimate this cost to 150 000 €/year for the considered terminal. Costs related to freight trams are extrapolated from Li (2011) with a confirmation by RATP (Paris urban public transport, managing classical tramway lines)[2]. They are estimated to 1,5 M€ per vehicle. For final delivery vehicles, we have asked to several manufacturers[3]. Finally, we can also consider other investment costs (related to software implementation, backoffice deployment or project management, among others) or non-monetary costs that have not been considered in this research. We synthesize all investment costs in Table 1.

Table 1. Synthesis of the main investment costs of building a new rail branch for a freight tramway

Type of cost	**Stakeholder involved**	**Unitary cost**
Tramway construction cost (railway)	Public administration	22.5 M€/km
Consolidation terminal	Public administration	0.15M€/year
City multimodal points	Public administration	Included in tram construction costs
Freight tramway vehicles	Service manager	1,5 M€/vehicle
Final delivery vehicles	Service manager	0.08 M€/vehicle
Other investment costs	Varia	Not considered yet
Non-monetary costs	Collectivity (city)	Not considered yet

Concerning operational costs, we can observe five main categories. The first that of operational costs of the tramway service itself, that are extrapolated from classical tramway services. Those costs include driving manpower and vehicle maintenance, and are estimated in all the railway line used for goods. The given value has been obtained from Li (2011) with a confirmation by APUR. To those costs we have to add those of the final delivery service

[1] Based on an experience feedback from the Paris Agency of Urbanistics (APUR) in January 2014.
[2] Confirmation made at SITL 2014, Paris, April.
[3] Four interviews made between July 2012 and December 2013.

and those of cross-docking. Final delivery service operational costs include the corresponding cross-docking costs, whereas upstream cross-docking costs have to be detailed (in the third category: other manpower costs). Infrastructure management costs are considered only for the new railway branch, and not for existing infrastructures, since in this second case maintenance costs can be absorbed by the passenger tramway service. Finally, we can define other maintenance costs related to the system operations and the back-office functioning. Those costs are synthesized in Table 2.

Table 2. Synthesis of the main investment costs of building a new rail branch for a freight tramway

Type of cost	**Stakeholder involved**	**Unitary cost per year**
Tramway operational costs (including maintenance)	Public administration	9.6 €/km
Final delivery service operational costs	Service manager	3.5 €/km
Other manpower costs	Service manager	0.03 M€/employee
Infrastructure maintenance	Public administration	0.3 M€/km
Other operational costs	Varia	0.2 M€

Finally we can define the benefits of the system. The first is that of the fee requested to use the service. Then, non-monetary benefits can be associated to the system: time savings (related to the time a carrier will earn if it uses the service), environmental benefits (greenhouse gas emissions, pollution and noise) and congestion decrease. For a fee, it will be the object of the analysis (to define a suitable fee). Time savings are calculated as in Gonzalez-Feliu et al. (2014). Greenhouse gas emissions and pollution will be estimated using Gonzalez-Feliu et al.'s (2013a,b, 2014) considerations, whereas noise and congestion will not be used for the moment. A summary of such benefits can be seen in Table 3.

Table 3. Synthesis of the main benefits of the system

Type of benefit	**Stakeholder involved**	**Unitary benefit per year**
Fee	Service manager	Defined during the analysis
Cost savings (distance + time)	Transport carrier	3.5 €/saved km
Greenhouse gas emission savings	Collectivity (city)	100 €/ton
Pollution decrease	Collectivity (city)	150 €/ton
Noise decrease	Collectivity (city)	Not considered yet
Congestion decrease	Collectivity (city)	Not considered yet

5. A first attempt of assessment

To assess the presented example, we need to summarize and complete the main hypotheses made. The project aims to construct 20 km of light railway to deliver peri-central zones in Paris to deploy a service of urban deliveries. Connected to this railway system, a final delivery service using commercial vehicles (less than 3.5T) of Gas-based vehicles is assumed. We set the update rates to 4%, the time horizon to 10 years from the construction achievement and no hypotheses on how money is obtained (loans, etc.) are made. In other words, we assume that the money is available and has not to be refunded back to a bank or loan institution. The target of the assessment it to find a suitable fee and a minimum usage of the system.

We present below a set of results illustrating a possible assessment of the example presented above. An SCBA framework is applied to the given scenario and parameters are changed (mainly the asked fee) to obtain a suitable situation.

In the best configuration results, the IRR (only economic) remains negative (about -8%) with a realistic fee (5€/pallet[4]). Those results seem not suitable, since the economic equilibrium is not found. However, we obtain a SERR of 5%, i.e., adding non monetary costs and benefits, the system seems to achieve a solid equilibrium. This equilibrium is made with a service using 2 trams per day (making each 3 shuttle trips), 50 vehicles for final deliveries (each vehicle with a total weight of 5-7 tons, i.e. similar capacity to classical 3.5 tons but with electric and gas vehicles the total weight of the empty vehicle increases for technical reasons) and a needed fee of 5€/pallet as said before. We took the hypothesis that 90 eq.pallets/day are passing the system.

The main non-monetary savings are estimated to be about 3,5 M€/year related to CO_2 and pollution and about 8,1 M€/year related to congestion and time. This second set of savings, which is the most important of the two, is also the most easy to show to private stakeholders, since those savings, that do not have a real monetary significance to collectivities, are instead easily translated into monetary gains (fuel savings and manpower cost decrease, mainly) to transport carriers. Remains however to pursuit the analysis with the facitilators and limitators of the system (in an approach like that of Gonzalez-Feliu and Morana, 2011), to be carried out using a qualitative analysis of semi-directive interviews, and could be done in a near future.

6. Conclusion

This paper presented briefly the interests and possibilities of using SCBA in assessing the suitability of urban rail logistics systems, by presenting the main element of the SCBA methodology and an example of application based on a possible configuration of the Paris Freight Tram. Railway urban logistics seems an interesting alternative for city distribution but needs to be planned and consensued among stakeholders, and SCBA can be a tool to support decisions, mainly in a group decision making context.

The proposed example shows that it is not always possible or suitable for a public authority to compensate costs only with economic benefits, mainly if it is not possible to ensure a threshold quantity of goods entering the system, or during the transition phase needed to reach this threshold. Moreover, railway seems more adapted to bring goods to the city, but not to do capillary distribution within the city center, mainly due to competition with passenger rail services and the difficulty to reach all parts of the territory. It is then important to focus rail freight services on canalizing goods to the city centers and aggregate them, then plan other

[4] According to Yves Guyon, president of City Logistics society, Lyon, 8€/ton is a suitable fee, and 5€ pallet is in general lower since in city logistics the main constraint for vehicles is volume and not weight.

types of final delivery services using more adapted modes (as for example soft modes or small, low-polluting road vehicles. However, final deliveries with small vehicles imply too many costs that are not compensated by benefits, so a more general approach including non-monetary costs and benefits is needed.

Results show that if those non-monetary costs and benefits are included in the assessment, the system can be justified, and stakeholders can be motivated to use it on the basis of quantifiable potential benefits for them. However, those methods need to be used to support the decision and negotiation process and not to justify or impose solutions without allowing discussion and consensus search. For those reasons, it is important to combine those approach with group decision methods and consensus search approaches (Gonzalez-Feliu et al., 2013c; Morana and Gonzalez-Feliu, 2014).

Remains to recall that the costs and benefits given here, as well as the assessment results, are examples using suitable data to make an example, and do not represent the real Paris Cargotram project in the configurations retained in the last meetings (those data are confidential). However, they represent a possible situation that need to be examined in-depth. Further developments are to define a more realistic scenario in collaboration with the Paris decision makers and to propose a set of possible situations to compare them. Moreover, the researches of facilitators and limitations, as well as of supporting the definition of a solid business model for such type of systems are objectives of possible further developments.

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