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Ex-ante assessment of urban freight transport policies

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Abstract

Many city public authorities have implemented measures to alleviate the negative effects of freight transport in urban areas, but these have often proved ineffective. The literature contains studies related to ex-post assessment of urban freight transport policies. This paper proposes a methodology for ex-ante assessment of their effects. The focus is the assessment of pollutant emissions. The application of the methodology to the inner urban area of Rome shows that an urban distribution centre can be more effective in reducing environmental externalities than policies based on vehicle fleet renewal.
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Keywords: Ex-ante assessment; urban freight transport; urban freight transport measures; truck pollutant emissions

1. Introduction

Technical improvements to vehicles are reducing the environmental impacts of individual vehicles, but these results have often been compromised by growth in transport demand. In general, the share of emissions of total traffic is about 20% to 30% from freight vehicles, depending on the local situation. Some surveys in Europe indicate that total urban freight transport accounts for 14% of vehicle-kilometres, 19% of energy use, and 21% of CO_2 emissions (Schoemaker et al., 2006). Urban freight is more polluting than long-distance freight transport owing to the frequency of short trips and stops. Fuel consumption increases sharply if the vehicle has to stop very often: with five stops in 10 km, fuel consumption increases by 140% (Martensson, 2005).

Thus to make urban mobility more sustainable measures to reduce the environmental impact of freight transport must be implemented. The measures implemented by cities to alleviate the negative effects of freight transport have often proved ineffective. A review of the various measures implemented and their results has been carried out by two large European projects, BESTUFS I and BESTUFS II. The two projects have produced handbooks and a best-practice guide (BESTUFS, 2007) in which regulation measures are addressed. These documents include case studies from European cities which provide details on measures implemented and their effects. The projects have found that

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many measures still fail to solve the problems for which they were implemented. A methodology to support the measures prior to implementation is thus crucial to evaluating ex-ante the possible effects.

The assessment of logistics policies is addressed by Hosoya et al. (2003) who developed a study for Tokyo. Starting from Stated Preferences (SP) surveys carried out there, they evaluated a number of logistics policies: bans on large trucks, road pricing, and construction of logistic centres. They present some models for evaluating firms' behaviour and interaction when the policies are implemented. Anderson et al. (2005) provide an ex-ante assessment of regulation measures in UK cities, including time windows and charging. Regulations based on time windows was addressed in Quak and de Koster (2006), who reviewed the state of practice in Dutch cities and provided an assessment of possible changes to current policy.

Analysis of stakeholder behaviour related to some measures has been proposed by Taniguchi and Tamagada (2005), who have developed a methodology for evaluating city logistics measures considering the behaviour of several stakeholders associated with urban freight transport. Considering five stakeholders, administrators, residents, shippers, freight carriers, and urban expressway operators, they performed a simulation on a test road network where a truck ban and tolling of urban expressways were introduced. The problem was formulated as an optimization problem.

The results of a survey in New York City are discussed by Holguin-Veras et al. (2005). Their study highlights the great complexity and nuances of commercial deliveries. A similar initiative was developed in the UK by Allen et al. (2003). Marcucci and Danielis (2008) investigated how receivers or transport operators make transport decisions on the potential use of an Urban Distribution Centre (UDC) in the city of Fano (Italy). The concept of logistic terminals (multi-company distribution centres) has been proposed in Japan to alleviate traffic congestion and reduce environmental, energy, and labour costs. UDC location and optimal size problems are addressed by Crainic et al. (2004). Scheduling and routing problems are investigated by Taniguchi et al. (2001).

Interactions among freight agents at an urban scale have been studied by Wisetjindawat et al. (2007), who proposed a micro-simulation model for urban freight movement in which the behaviour of freight agents and their interactions in supply chains are incorporated. Application to the Tokyo Metropolitan Area is also described.

Models are used to estimate a wide range of impacts including social, economic, environmental, and financial. For the estimation of social impacts, resulting from reduction of traffic congestion and crashes, and economic impacts, due to changes in fixed and operation costs, some proposed formulations provide a combination of input-output approach with the multi-step modelling process (Taniguchi et al., 2001); Taylor and Button (1999) give an application example. Environmental impact models predict air pollution (NO_x, CO_2, etc.) and noise levels. For a state of the art on this topic, see Kroon et al. (1991). Some applications are reported in Taniguchi and van der Heijden (2000) and Ma (1999). The economic-financial impacts usually refer to techniques based on cost-benefit analysis (Ooishi and Taniguchi, 1999). For recent developments in urban freight studies, see Taniguchi and Thompson (2008).

Many of these studies consider only some aspects of problems related to implementing urban freight transport policies (e.g., demand estimation and impact evaluation). Some of them use SP surveys to catch the stakeholder's behaviour, but the possible advantages of this type of survey are obtained at the price of introducing some distortion in the results and in the models calibrated. Distortions stem from the possible differences between stated and real-choice behaviour (Hensher et al., 1988).

This paper aims to provide an integrated ex-ante assessment of urban freight transport policies. The availability of a reliable tool for ex-ante assessment is the key in the decision making processes dealing with the choice of measures. As several studies have shown, the best solutions have come from a mix of measures. The proposed methodology makes it possible to assess one or a mix of measures, including traffic regulation and distribution schemes based on a UDC. The methodology is based on the use of Revealed Preference (RP) surveys. The paper presents the overall assessment framework and provides a detailed description of the methodology for the estimation of pollutant emissions from road vehicles. The methodology is illustrated by an application to the inner area of the city of Rome.

2. The Proposed Methodology

The proposed methodology focuses on the quantification of impacts due to different freight transport policies implemented at an urban scale in terms of environmental sustainability and examination of the attainment of pre-fixed objectives. The proposed methodology can be schematised as follows (Figure 1):

- *transportation system identification*: the objective of this first phase is the identification of the elements of the system under analysis and their relationships;
- *urban freight transport policy identification*: some supply scenarios can be defined in the function of different measures; these scenarios can be built together with interested stakeholders (DfT, 2003); this phase is integrated and related to transportation system identification;
- *modelling freight transportation system*: the relevant interactions among the various elements of a freight transportation system can be simulated with mathematical models (Nuzzolo et al., 2008); this phase provides the input (such as link flows and level of service attributes) for the phase of impact estimation;
- *impact estimation* due to freight transport; this phase estimates the impacts due to freight transport; for example, the emissions from road transport can be calculated using methodologies found in the literature (Eggleston et al., 2000) and specified for the system analyzed;
- *goal achievement assessment*: in this phase the impacts evaluated for the proposed supply scenarios are compared with targets.

2.1. Transportation system identification

The aim of this phase is the definition of the elements that make up the analysis system and of their relationships. The elements of interest pertain to three spheres:

- the demographic, economic and spatial characters of transport demand,
- the supply of transport and logistics infrastructure and services, and
- the external environment as it plays a role in the estimation of some impacts.

2.2. Urban freight transport policy identification

To identify possible urban freight transport policies and to build different scenarios, it is important to take into account the stakeholders' point of view, as confirmed in the UK. In fact, the UK Freight Quality Partnerships (FQPs) can be considered a key factor for studying and implementing successful city logistics initiatives (DfT, 2003). Typically a FQPs group aims to identify problems, determine appropriate measures and sustainable best practice, and to implement them.

A range of measures are available, of which some are already found in cities, while some are still at the proposal or trial stage. They may be divided into four classes:

- freight traffic regulation: this class includes access (to areas or to individual roads), parking, loading and unloading regulation;
- physical infrastructure: these measures are related to links of the urban transport networks (e.g., underground freight distribution networks) or to nodes (e.g., Urban Distribution Centres);
- Intelligent Transportation Systems (ITS): this class includes traffic information systems and systems for route optimisation and freight capacity exchange;
- loading units and vehicles: these measures are related to standards for loading units and to use of unconventional vehicles (e.g., electric vehicles, metropolitan railways and trams).

This paper deals with a mix of measures mainly belonging to the first and second classes. A conceptual analysis of traffic regulation measures is in the work by Comi et al. (2008) who also includes an in-depth empirical analysis with results of ex-post evaluations for the cities of Rome and Milan.

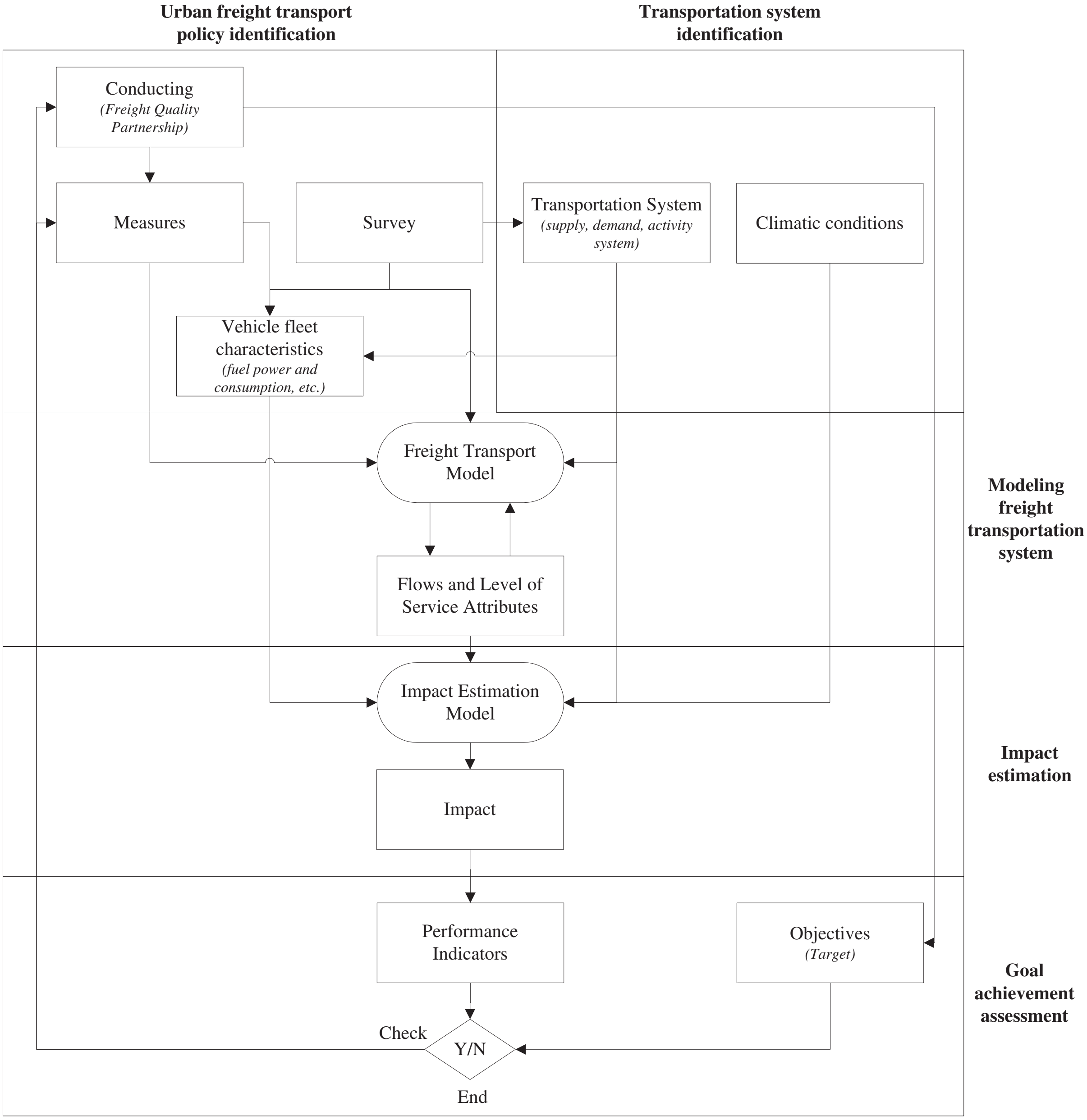

Figure 1 The used methodology

2.3. Modelling freight transportation system

The definition of freight service supply and the estimation of its impacts requires accurate knowledge of urban/metropolitan freight demand that, for forecast scenarios, can be developed using a modelling system. In the literature we identified several methods and models developed for simulating freight demand but many of them are developed for interregional or national contexts. They are hardly useful for urban and metropolitan areas where mainly Light Goods Vehicles (LGV) with a gross laden weight less than 3.5 tonnes are used. The modelling solutions are not able to deal explicitly with the mechanisms underlying demand in urban and metropolitan areas, where transport is mainly related to the distribution of final products from wholesalers and restocking centres to the economic activities located in the area. For the analysis of urban or metropolitan freight demand, good results have been obtained with partial share models with a modelling structure similar to that used for passenger transportation simulation (Nuzzolo et al., 2008; Russo and Comi, 2009).

A modelling system has been recently developed in Italy (for more details and for results of its applications, see Nuzzolo et al., 2008). It simulates the average flow of goods/deliveries/vehicles (*Q/ND/VC*), with their relevant characteristics, between zone *o* and zone *d* in a study area within a time period *h*. The proposed modelling system consists of three levels:

- commodity level (*Q*), in which the freight O/D matrices in quantity are estimated from socio-economic data,
- delivery level (*ND*), in which from the freight O/D matrices in quantity, the model gives the flows of deliveries for each od pairs;
- vehicle level (*VC*), in which the delivery flows are converted to obtain the O/D matrices of freight vehicles.

The relevant characteristics are:

- origin and destination (respectively *o* and *d*),
- time period (*h*),
- freight type (*s*), e.g., fruit, clothing,
- restocking type (*m*), if the restocking is done by the receiver or the sender in own account, or by third parts,
- average delivered/picked freight quantity (*q*), and
- vehicle type (*v*).

2.4. Impact estimation

Design and evaluation of transportation systems, in addition to performance variables perceived by the users, require the modelling of impacts borne by the users, but not perceived in their mobility choices, and of impacts on non-users. Examples of the first type include indirect vehicle costs and accident risks with their consequences. The impacts on non-users include those for other subjects directly involved in the transportation system, such as costs and revenues for the producers of transportation services, and impacts "external" to the transportation system (or market). Examples of externalities are the impacts on the real estate market, urban structure, or on the environment, such as noise and air pollution. Often these functions are named for the specific impact they simulate (e.g., fuel consumption functions or pollutant emission functions). Some impacts can be associated with individual network links and depend on the flows. The impacts include:

- impacts on users (e.g. travel time and generalized travel cost), and
- impacts on non-users, externalities (e.g., air pollution and energy consumption).

Air pollution has received much attention recently. It is one of the main impacts on the transportation system and is worst in urban areas. As mentioned, this paper focuses on the ex-ante assessment of a policy mix to reduce environmental impacts due to urban freight distribution. Considering that air quality models are indispensable tools to assess the impact of air pollutants on human health and the urban environment, a review of emission models is proposed by Gokhale and Khare (2004), and an evaluation of traffic pollution as a function of traffic emissions, meteorological conditions, and street configuration is proposed by Berkowicz et al. (2006).

Emissions are highly dependent on the speed of vehicles. In the literature we find some examples in the application of these models. Taniguchi and van der Heijden (2000) present a model for evaluating City Logistics initiatives in terms of CO_2 emissions. One of the most extensive traffic emission modelling methods used within the European context is the COPERT (COmputer Programme to calculate Emissions from Road Transport) model, promoted by the European Environmental Agency within the CORINAIR programme. Even if the model was specified for estimation of national emissions of traffic related pollutants, in this study the methodology was adapted for the urban and metropolitan contexts.

A large quantity of laboratory data were processed statistically within COPERT, resulting in vehicle emission factor expressions as function of the vehicle travel speed. Expressions are provided for different vehicle categories with differentiation between vehicle types (passenger cars, vans, trucks, etc.), fuel used, engine capacity or weight and perhaps most important, the emission legislation category. Besides the basic emission factors, corrections are also provided accounting for cold starts and degradation of the emission reduction equipment with the age (mileage) of vehicles. This model was chosen because it is extremely flexible and easy to use.

The estimation of pollutants by road vehicles can be considered as the sum of three components:

$$E_i = E_{hot,i} + E_{cold,i} + E_{vap,i} \qquad [t/year] \tag{1}$$

Where, $E_{hot,i}$ is the hot emissions of pollutant i during stabilized (hot) engine operation; they can be estimated as

$$E_{hot,i} = \sum\nolimits_{jk} n_j \cdot m_{jk} \cdot e_{hot,ijk} \qquad [t/year] \tag{2}$$

With, n_j, number of vehicles of class j in circulation during the reference year,
m_{jk}, mileage per vehicle driven on roads of type k by vehicles of class j,
$e_{hot,\ ijk}$, average fleet representative baseline emission factor for pollutant i, relevant for vehicle class j, operated on roads of type k, with thermally stabilized engine and exhaust after treatment system.

$E_{cold,i}$ are the cold emissions during transient thermal engine operation (cold start). A distinction in emissions during the stabilized and warming-up phases is necessary because of the substantial difference in vehicle emission performance during those two conditions since concentrations of most pollutants during the warming-up period are many times higher than during hot operation and a different methodological approach is required to estimate over-emissions during this period; this type of emission can be calculated as:

$$E_{cold,i} = \sum\nolimits_{j} \beta_{i,j} \cdot n_j \cdot m_j \cdot e_{hot,ij} \cdot \left(e_{cold,ij} \big/ e_{hot,ij} - 1 \right) \qquad [t/year] \tag{3}$$

With, β_j, fraction of mileage driven with cold engines or catalyst operated below the light-off temperature for pollutant i and vehicle category j,
m_j, total mileage per vehicle in vehicle class j,
$e_{cold,ij} / e_{hot,ij}$, cold over hot ratio for pollutant i, relevant to vehicles of class j;

$E_{vap,i}$ are the evaporative emissions given by evaporative NMVOC emissions from gasoline; this term evaporative emissions refers to the sum of all NMVOC emissions not derived from fuel combustion. They can be estimated as:

$$E_{vap} = 365 \cdot \sum\nolimits_{j} n_j \cdot m_j \left(e_{di} \cdot S_{ci} \cdot S_{fi} \right) + R_i \qquad [t/year] \tag{4}$$

With, e_{di}, emissions factor associated with the ambient diurnal temperature variation,
S_{ci}, hot and cold emissions factor, for vehicles equipped with carburetor,
S_{fi}, hot and cold emissions factor, for vehicles equipped with electronic injection,
R_i, losses during running.

For more detail, see Eggleston et al. (2000).

2.5. Goal achievement assessment

The supply scenarios can be evaluated with respect to indicators of efficiency, social sustainability (indicators related to congestion and safety), and environmental sustainability. The values obtained for the indicators are compared with some reference values (targets). The indicators chosen for this stage of the ex-ante assessment could be monitored in the ex-post assessment to track their real evolution over time. These indicators could be developed considering the set of variables promoted by European Environment Agency (TERM, Transport and Environment Reporting Mechanism). In fact, the TERM indicator list covers the most important aspects of the transport and environment system (driving forces, pressures, state of the environment, impacts and societal responses). It represents a long-term vision of the indicators that are ideally needed to monitor the progress and effectiveness of transport and environment integration strategies.

In general, other types of impacts could be considered as such financial impacts of reduced costs to carriers and shippers, and energy consumption by changing the amount of energy used.

3. Application to a Real Case

The methodology has been applied to the city of Rome to assess the effects of some measures and to understand the current situation and which measures could be introduced to improve it. The area considered is the inner city area, of about 6 square kilometres, with more than 50,000 inhabitants and less than 130,000 workers.

The municipality faces the challenge of supporting the freight stakeholders while at the same time reducing congestion and environmental impacts due to traffic (including freight). Within the study area, there are local conditions that oblige freight vehicles to stop for loading and unloading outside legal spaces. There is a problem of meeting the needs of freight vehicles that are delayed by other traffic and that encounter problems loading and unloading, especially because of insufficient parking spaces. Currently, there are some restrictions on trucks. Access is permitted only to vehicles with certain emissions characteristics (no access to pre-Euro vehicles) and with a gross laden weight of less than 3.5 tonnes.

As described in the previous section, one step in the analysis is surveys, and for this reason the study has been supported by two types of surveys:

- traffic surveys and traffic counts of commercial and private vehicles and interviews with truck drivers to investigate the logistics chains of freight distribution, and
- interviews with retailers for gaining information about retail trade in the study area for each freight type.

The surveys were carried out in 2008, and consist of: traffic counts carried out on weekdays in November 2008, more than 500 interviews with truck drivers and about 600 interviews with retailers. These surveys revealed that the main type of freight moved in the study area is food, household, and health products (about 65%), and that distribution has two peak periods, one in the morning (8:00 to 10:00 a.m.) and one in the afternoon (3:00 to 4:00 p.m.). The incidence of freight vehicles is about 6% (about 14,000 vehicles per day), and the freight traffic is composed of:

- 57% goods vehicles with a gross laden weight less than 1.5 tonnes,
- 33% goods vehicles smaller than 3.5 tonnes,
- 10% vehicles with gross laden weight less than 8.5 tonnes.

Thus, the most common vehicle type is a light goods vehicles (maximum gross laden weight 3.5 tonnes) characterized by an average of 3.2 deliveries per trip. A comparison of the obtained results with those obtained in a similar survey carried out in 1999 indicates that in the area the number of freight vehicles has increased by about 1.6% per year.

The composition of freight flows is given in Table 1. The analysis highlights that in the study area about 23,000 tonnes are moved each day. Of this, 30% consists of food (about 16% is directed to restaurants and bars, and 14% to retailer) and the remaining 70% is other end-consumer products (e.g., household and health products).

The distribution of vehicles in terms of emissions is reported in Table 2. Although pre-Euro vehicles are not permitted in the study area, it was revealed that about 6% are pre-Euro vehicles. About 93% are diesel vehicles, and more than 59% respect the Euro 3 standards.

Table 1 Freight quantity moved in the study area

Freight type	Loading *[kg/day]*	Unloading *[kg/day]*	Loading *[%]*	Unloading *[%]*	Total *[%]*
Foodstuffs	20,956	6,930,377	1%	33%	30%
Health products	233	177,004	0%	1%	1%
Household products	548,592	4,304,650	26%	20%	21%
Other	1,534,586	9,681,328	73%	46%	48%
Total	2,104,367	21,093,358	100%	100%	100%

Table 2 Composition of freight flow

Fuel	Emission Standards					Total
	pre-Euro	*Euro 1*	*Euro 2*	*Euro 3*	*Euro 4*	
Gasoline	0.7%	0.8%	0.0%	1.9%	0.8%	4.2%
Diesel	3.9%	4.0%	6.2%	57.1%	21.5%	92.7%
LPG	0.0%	0.0%	0.0%	0.0%	1.2%	1.2%
CNG	1.7%	0.0%	0.0%	0.2%	0.0%	1.9%
Total	6.3%	4.8%	6.2%	59.2%	23.5%	100.0%

The analysis highlights the difference in terms of trip length. Average trip length is:

- light goods vehicles with gross laden weight less than 3.5 tonnes,
  - gasoline, LPG and CNG: 16 km per tour, and
  - diesel: 20 km per tour.
- light goods vehicles with gross laden weight more than 3.5 tonnes,
  - gasoline: 24 km per tour, and
  - diesel: 26 km per tour.

The described methodology was applied to test four different scenarios:

- non-intervention and vehicle demand growth following the previous trend (+1.6%) without enforcing the control access (SC0);
- intervention and enforcing control for access to pre-Euro vehicles and for parking (SC1);
- access prohibition to vehicles that do not comply with the Euro 2 standards and market entry of Euro 5 standards (SC2);
- previous scenario (SC2) with creation of an Urban Distribution Centre (SC3).

As stated, the methodology was specified for the evaluation of environmental impacts. In particular, the CORINAR methodology was applied and the demand modelling system recalled in the previous section has been specified, calibrated and validated for this study area. The effects of the implementing each scenario was evaluated in differential terms, i.e. as variations and differences of the variables representing them, between the project and non-project states. The latter, is defined as the option to maintain the present state of the system with the projects already decided which are not subject to the evaluation. In the following, the effects in terms of CO_2 and external costs caused by main pollutants are described. In particular, referring to CO_2, Figure 2 shows the reduction in emissions due to the implementation of scenarios. In 2008, the CO_2 emissions related to goods vehicles has been estimated at about 28,000 tonnes/year.

The effect of non-intervention increases CO_2 emissions, and the same happens if in the near future the public authorities enforce access control (SC1). The best results come from the introduction of a multi-company Urban Distribution Centre (UDC) with no implementation of other freight traffic restrictions. The implementation of a UDC gives a reduction of about 15% of vehicle-km and determines a reduction in terms of CO_2 of about 24%. From the public authority point of view, the cost has to be considered with respect to externalities as well. The externalities have been considered in terms of pollution reduction. The main results for each scenario are reported in Figure 3, where the external costs due to pollution were obtained using the guidelines given by INFRAS et al. (2007). The introduction of a UDC could achieve a reduction in external costs of about 26%.

In other words if the public authorities want to reduce the external costs borne by the community, they will stimulate replacements towards more eco-friendly vehicles and the optimization of freight distribution by a UDC (Table 3).

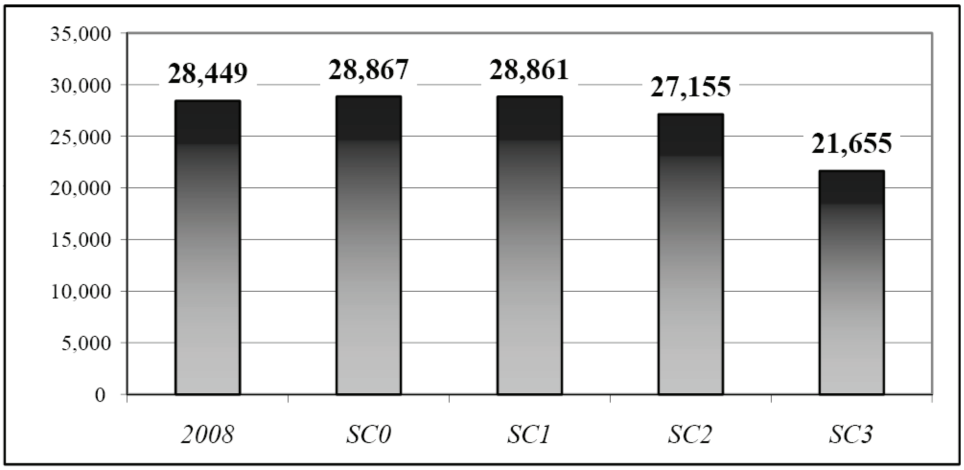

Figure 2 Emissions of CO_2 [t/year]

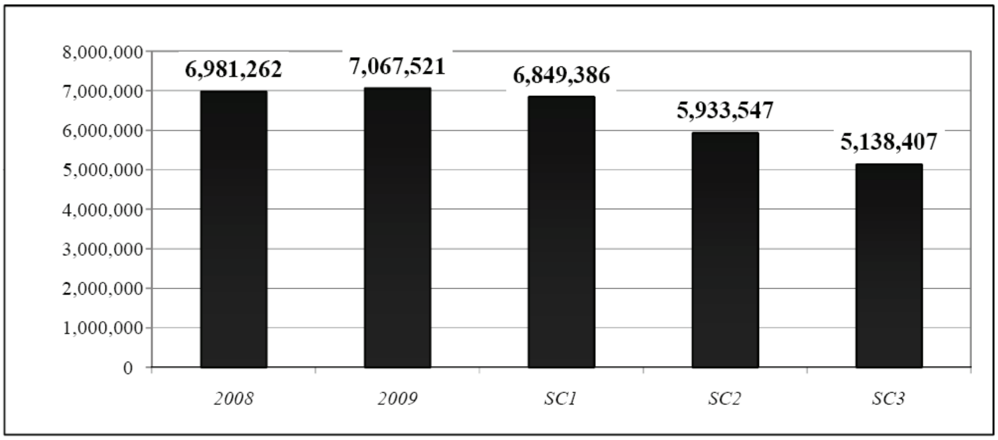

Figure 3 External costs per scenario [€/year]

Table 3 Effects of scenario implementation

Scenario	Unit	SC0	SC1	SC2	SC3
Variation respect to 2008	€/year	+ 86,259	-131,875	-1,047,715	-1,842,855
Vehicle replacement	vehicle		523	2,541	523
Saving for vehicle	€		252	412	

Finally, comparing each scenario in terms of external costs, we see that, to reduce externalities, the authorities could refer to SC1, SC2 or SC3. The reduction of pollution has been estimated as about:

- € 130,000 per year, this amounts to a saving of about € 520 per vehicle, which could justify an investment by the public authority in terms of extra-costs to promote vehicle renewal (scenario SC1),
- € 1 million per year, this amounts to a saving of about € 400 per vehicle, which could justify an investment of the public authority in terms of extra-costs to promote the vehicle renewal (scenario SC2), and
- € 1.8 million per year, this saving could justify an investment by the public authority in terms of extra-costs for the environmental protection of this historic study area (scenario SC3).

To evaluate the economic convenience of scenario SC3, a cost-benefit analysis was carried out. Its results are reported in Table 4. As shown, the Internal Return Rate is higher than 18% and it demonstrates the convenience of implementing a UDC.

Table 4 Cost-Benefit analysis of scenario SC3

Building costs	[€]	4,200,000
Handling equipments	[€]	200,000
Management costs	[€/year]	1,000,0000
Operating and building time		10 + 3
Reduction of pollution	[€/year]	1,842,855
Net Present Value (NPV)	[€]	1,364,477
Internal Return Rate (IRR)		18.1%

4. Conclusion

Today, most cities have to deal with the large number of trucks and vans delivering goods in the urban area while preserving the economic sustainability of the businesses located in the city and, at the same time, the environmental quality.

Many measures to reduce the negative effects of freight transport in cities in Europe and around the world have been implemented without ex-ante assessment of the impacts and have not been effective. In the paper, an ex-ante assessment methodology of urban freight transport policies, with a focus on the assessment of pollutant emissions, has been presented.

The methodology was applied to the city centre of Rome, a historic area where problems of environmental protection are particularly urgent. Useful indications in terms of policy making were derived. The benefits from the point of view of a public authority of regulation and other measures, including an Urban Distribution Centre (UDC), have been estimated. Measures that are able to change the load factor and reduce the vehicle-kilometres travelled, such as the introduction of an UDC, prove to be more effective in terms of reducing pollutant emissions than measures based on a change in vehicle fleet composition. All measures produce a reduction of social costs stemming from pollutant emissions, which justifies the earmarking of extra-funds for measures aimed at protecting the environment.

The methodology proposed could be further developed in the near future with a micro-simulation traffic module. The simulation of the driving cycle in real traffic conditions would increase the accuracy of the estimates of the pollutant emissions.

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