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Assessing the external costs of urban transport investments: a socioeconomic analysis

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Abstract

Transport is a considerable source of pollution in cities. The social impacts of transport activities result from emissions of pollutants, greenhouse gases, and noise, as well as traffic accidents. Not every urban investment that reduces such 'external' effects of transport will be found acceptable by the public. In order to assess and communicate the social impacts of investments, it is necessary to calculate external costs appropriately. This article discusses issues with estimating the social costs and benefits of transport-related investments in cities. The article also provides a classification of social benefits from urban transport investments and proposes a general methodology for estimating such benefits. Due to the versatility of urban investments, there can be no single, universal method. The article proposes methods for analysing social costs and benefits on the basis of two sample urban investments.

Introduction

Along with the residential sector, transport is a major source of pollution in cities. For example, in Warsaw transport is responsible for 60% of total emissions of PM_{10} and 50% of nitrogen oxide emissions (Badyda and Kraszewski, 2010). For many people, the quality of transport (type of transport, level of congestion, and public availability) is a decisive factor in choosing a place to live. The management of urban (freight, individual, or public) transport is the responsibility of city authorities. In strategic terms, management requires appropriate planning and then implementation (often very costly) of investments in transport infrastructure and means. City authorities may obtain European funds for such projects. However, first they have to prove that the investment, which may even be unprofitable in financial terms, will benefit inhabitants. Such benefits, referred to as social benefits, must be quantified in monetary units. To that end, it is necessary to carry out a Social Cost Benefit Analysis (SCBA). This is a particularly challenging task as, in the case of urban investments, it is difficult to estimate or forecast actual numbers of passenger- or tonne-kilometres. This article will discuss issues connected with estimating social costs and benefits of transport-related investments in cities. The article also provides a classification of social benefits from urban transport investments and proposes a general methodology for estimating such benefits. Due to the versatility of implemented urban investments, there is no single, universal method. The article proposes methods for analysing the social costs and benefits of two urban investments specifically: replacement of an urban public transport fleet and construction of a consolidation centre.

The literature review

Each kind of transport activity generates both benefits and costs. While the benefits are provided mainly to the people who pay for the transport, some costs are incurred by others or by the society as a whole. Therefore, transport costs may be categorised as 'internal' or 'private' – those incurred by persons engaged in the transport activity – or so-called 'external costs' (COM, 1995) (Table 1).

Internal costs incurred by transport participants include the costs of vehicle maintenance and depreciation, costs to the driver's time and safety, and internalised portions of external costs, i.e. the costs of environmental pollution or greenhouse gases emissions, which are covered by the public tax system. Internal costs also include the very important cost of accessing infrastructure, which may account for as much as 60% of internal costs (Limao and Venables, 2000a). Internal costs are the most fundamental factor in transport competition, which affects demand for transport and selection of transport routes. Limao and Venables note that an increase in transport costs by 10% leads to a decrease in transport volume by 20% (2000b).

Another group of costs is comprised of external costs arising from transport activities but not transferred to the user via the market (Bąk, 2009). These result from greenhouse gases and pollutants emissions, noise, road accidents, and congestion (Janic, 2007). These also include the costs of planning, construction, maintenance, administration, and operation of the transport infrastructure, which are not accounted for in charges and taxes (Saighani and Sommer, 2019). The effect of external costs on the society is presented in Table 2.

Greenhouse gas emissions have important global impacts, regardless of their place-of-origin (Althor, Watson, and Fuller, 2016). As opposed to greenhouse gases, pollutant emissions depend on the kind of transport as well as the time and place of their production. The social costs of emissions originating in peak hours in city centres are different from the social costs of emissions produced on motorways in rural areas. The costs of noise, similarly to the costs of pollution, depend on their place of origin, and additionally on the time of day when they are produced (Jochem, Doll, and Fichtner, 2016). The same level of noise made by a vehicle passing at night has a different effect on humans than it would during the day. Congestion is the external cost most difficult to measure as it is connected with many factors, i.e. longer travel times, greater costs in vehicle maintenance, the costs of delays, and ensuing decreases in transport operations reliability (COM, 1995). Congestion levels depend on types of infrastructure,

Table 1. Cost categories (COM, 1995)

Cost categories	Costs	
	internal	external
Transport Expenditures	fuel and vehicle costs; tickets/fares	costs paid by others (e.g. provision of free parking)
Infrastructure Costs	user charges, vehicle taxes and fuel excises	uncovered infrastructure costs
Accident Costs	costs covered by insurance, personal accident costs	uncovered accident costs (e.g. pain and suffering imposed on others)
Environmental Costs	personal drawbacks	uncovered environmental costs (e.g. noise disturbance to others)
Congestion Costs	personal time costs	delays/time costs imposed on others

Table 2. Effects of social costs (Bąk, 2009)

s/n	Categories of social costs	Social effects
1	Greenhouse gases	global warming, glacial ice melting, floods, hurricanes, droughts, sea level rising, changes in sea current circulation
2	Pollutants, i.e. NOx, SOx, Nm-Voc	acid rains, pulmonary and circulatory diseases, cancer, decreased crops
3	Solid pollutants, i.e. particulate matter (PM_{10}, $PM_{2,5}$)	irritation of eyes, skin and airways, pneumoconiosis, allergies and poisonings
4	Noise	loss of hearing, raised stress levels, raised blood pressure, hormonal changes, reduced satisfaction with leisure activities, discomfort during rest, sleep disorders, headaches
5	Traffic accidents	deaths and disabilities of persons involved in accidents, costs of rescuing and rehabilitating the injured, costs of emergency services, production losses, losses of expenditures invested e.g. in education
6	Congestion	extended travel times, increased costs of vehicle operation and maintenance, costs connected with vehicle depreciation and employment, deterioration of service reliability as a result of delays

their capacities, and traffic levels. Some costs of traffic accidents are partially internalised in the costs of motor insurance while others still constitute external costs. In addition to the typically social impact of traffic accident casualties, which is difficult to express in monetary terms, traffic accidents also generate costs related to rescuing and rehabilitating people injured in accidents, and maintaining emergency services, such as police, ambulance, and fire services.

Internalisation of external costs of transport is one aspect of the sustainable development of transport (Kotowska, Pyza & Sivets, 2014). It is also one of the major priorities of the EU's transport policy. Internalisation of external costs aims at making transport users pay the costs of all effects of transport, in other words, it is aimed at transforming all external costs into internal costs (COM, 1995). However, the question of how to estimate all such costs is problematic.

Since the onset of the 21st century, many publications have attempted to estimate the external costs of transport, i.e. (RECORDIT, 2003; UNITE, 2003; Schreyer et al., 2004; Holland et al., 2005; HEATCO, 2006; TREMOVE, 2006; Maibach et al., 2007; EX-TERMIS, 2008; Korzhenevych et al., 2014). In 2016, the Centre for EU Transport Projects published precisely estimated external costs of road transport, for the needs of transport investment projects implemented with the support of EU funds, in *Vademecum Beneficjenta* (Archutowska et al., 2016), which refers to the aforementioned publications to a large extent, in particular to Korzhenevych et al. As opposed to the estimates of other publications, this document's calculations take into account the kind of vehicle, its Euro standard, and the cost centre, and therefore seems suitable for estimating the external costs of urban investments. Thus the aforementioned document is the basis of the method provided in this paper for estimating external costs of transport.

Social benefits of urban transport investments

Organisation of urban transport is a complex process. Urban transport includes urban freight transport, public transport systems, and individual transport. Investment projects implemented within cities may be divided into three groups:

- investments in the generally accessible linear and point infrastructure, i.e. traffic arteries in cities, facilities for EV charging, Park&Ride and Bike&Ride systems, vehicle monitoring systems (e.g. in limited traffic zones), and intelligent transports systems (ITS);
- investments in infrastructure dedicated to specific forms of transport in cities, e.g. dedicated priority lanes for public transport, shared bus and tram stops, cycling paths, and unloading bays;
- investments in means of transport – e.g. low-emission vehicles and electric vehicles.

Such investments do not bring direct benefits to the investors (their Financial Net Present Value is negative). However, they generate social benefits by decreasing the external costs of transport. Therefore, they may be subsidised with European Union funds. The prerequisite for obtaining a grant is an economic analysis which additionally accounts for estimated social benefits (the Economic Net Present Value is positive) (Figure 1).

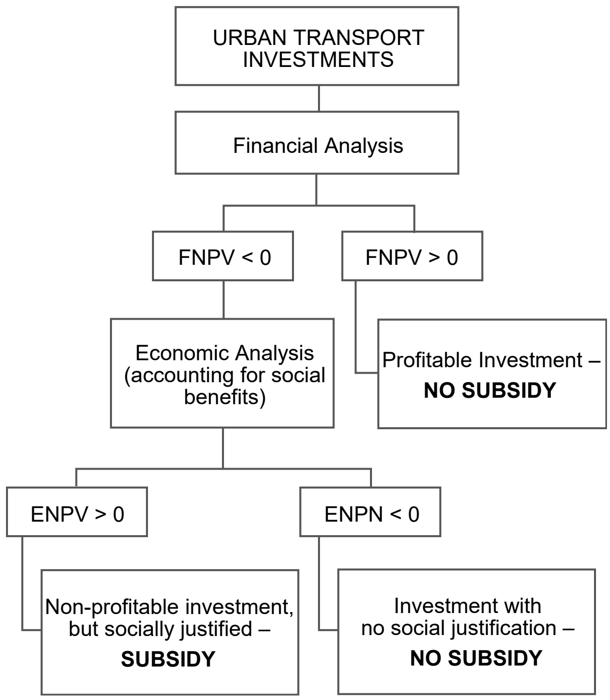

Figure 1. Diagram of the procedure of obtaining EU grants (based on (Jaspers, 2015))

General assumptions of the analysis

The social benefits of introducing particular solutions in urban transport result from a reduction in external costs upon completion of the given investment. Thus, measurable social benefits (B) can be seen as the difference between external costs generated before C_b and after C_a introduction of a given solution.

$$B = C_b - C_a \tag{1}$$

The most important external costs of urban transport include environmental pollution, climate changes, traffic accidents, congestion, and noise. In most cases, social benefits come from two things:

- reduced unit costs;
  This happens in with solutions such as purchasing low-emission vehicles, introducing low emissions zones, and establishing bus-only lanes.
- reduced numbers of passenger- or tonne-kilometres;
  This happens in the case of solutions applying to, e.g., the traveling salesman problem. They are exemplified by solutions such as establishing urban consolidation centres and using public transport to make deliveries within an urban area.

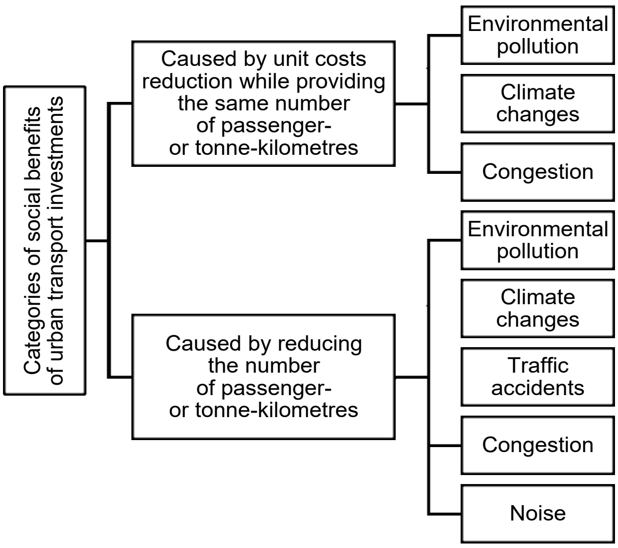

Figure 2. Categories of social benefits of urban transport investments

Assigning the analysed investment to one of the two major categories is the first step to be completed, before assessing social benefits and costs (Figure 2).

Selected examples of estimated social benefits from urban transport investments

Purchase of low-emission buses

It is relatively easy to specify the social benefits of purchasing low-emission buses. The greatest benefit is a reduction in pollutant emissions B_{pe}, which may be estimated in the following way:

$$B_{pe} = \sum_{i=1}^{n} \text{CPE}_i \cdot (N_i - N_i') \cdot \text{MD} \qquad (2)$$

where:

CPE_i – unit costs of pollutant emissions by a vehicle with Euro standard i [EUR/vehicle-kilometre],

n – number of analysed Euro standards, $n = 7$ for Euro 0 – Euro 6,

N_i – number of analysed Euro i standards vehicles before implementing the investment,

N'_i – number of analysed Euro i standards vehicles after implementing the investment,

MD – mean distance covered by the vehicle.

The climate change costs are directly proportional to the level of fuel consumption of the vehicle. Newer vehicles, with improved emission standards, consume less fuel. Similarly to the case of environmental pollution, the benefits of reducing the external costs of climate change B_{CC} by replacing the vehicle fleet may be formulated as follows:

$$B_{cc} = \sum_{i=1}^{n} \text{CCC}_i \cdot (N_i - N_i') \cdot \text{MD} \qquad (3)$$

where:

CCC_i – unit costs of climate change generated by a vehicle with Euro standard i [EUR/vehicle-kilometre],

N_i, N'_i, MD – as above.

In this case, the costs of noise, traffic accidents, and congestion do not change.

Construction of a consolidation centre

A consolidation centre is a warehouse where smaller consignments are combined into larger cargoes. This makes it possible to deliver them using fewer vehicles, which leads to reducing the number of tonne- kilometres (Pfohl 2001). The key external effect of constructing a consolidation centre will be reductions in pollution and greenhouse gas emissions as a result of decreasing numbers of tonne-kilometres. Moreover, other external costs will also go down: traffic accidents, congestion, and noise.

The benefits of reducing pollutant emissions , in terms of decreased numbers of vehicle-kilometres, may be computed with the formulas:

$$B_{pe} = \text{CPE}_{mu} \cdot (\text{VKM} - \text{VKM}') \qquad (4)$$

$$\text{CPE}_{mu} = \frac{\sum_{i=1}^{n} \text{CPE}_i \cdot N_i}{N} \qquad (5)$$

$$\text{VKM} = N \cdot \text{MD} \qquad (6)$$

$$\text{VKM}' = N' \cdot \text{MD}' \qquad (7)$$

where:

CPE_{mu} – mean unit cost of pollutant emissions generated by vehicles serving the warehouse [EUR/vehicle-kilometre],

VKM – number of vehicle-kilometres before implementing the investment,
VKM' – estimated number of vehicle-kilometres after implementing the investment,
MD' – mean distance covered by a vehicle after implementing the investment,
MD, N_i – as above,
N – number of vehicles serving the warehouse before implementing the investment,
N' – number of vehicles serving the warehouse after implementing the investment.

The benefits of decreasing greenhouse gases emissions may be formulated as follows:

$$B_{CC} = \text{CCC}_{mu} \cdot (\text{VKM} - \text{VKM'}) \quad (8)$$

$$\text{CCC}_{mu} = \frac{\sum_{i=1}^{n} \text{CCC}_i \cdot N_i}{N} \quad (9)$$

where:
CCC_{mu} – mean unit cost of greenhouse gas emissions by vehicles serving the warehouse [EUR/vehicle-kilometre],
VKM, VKM', N_i, N, CCC_i – as above.

Reducing the number of tonne-kilometres will also lead to fewer traffic accidents B_{ac}, congestion B_{con}, and noise B_n. These can be formulated as follows:

$$B_{ac} = C_{ac,j} \cdot (\text{VKM} - \text{VKM'}) \quad (10)$$

$$B_{con} = C_{con} \cdot (\text{VKM} - \text{VKM'}) \quad (11)$$

$$B_n = C_n \cdot (\text{VKM} - \text{VKM'}) \quad (12)$$

where:
C_{con} – unit costs of congestion [EUR/vehicle-kilometre],
$C_{ac,j}$ – unit marginal costs of traffic accidents [EUR/vehicle-kilometre] in country j,
C_n – unit costs of noise [EUR/vehicle-kilometre].

The calculation of external costs requires detailed identification of the numbers and structures of vehicles entering a given area, specifying their kinds, carrying capacities, and Euro standards. The data may be gathered via primary research (e.g. counting the numbers of vehicles entering and leaving any given area, taking into account their kinds, carrying capacities, and Euro standards, or surveys). Should there be no possibility of conducting precise primary research, it is possible to use secondary data gathered by motor vehicle departments or statistical services with regard to, e.g., the kinds and structures of vehicles registered in a given region.

Another factor necessary for specifying the external costs of transport is the mean carriage distance. Due to lacks of data, this is one of the most challenging estimates to make. It is possible to do so by identifying representative routes as bases for the mean carriage distance in a particular area. In the cases of activities aimed at restricting vehicle access in a given area, the mean carriage distance may be estimated using the following formula:

$$\text{MD} = 2 \cdot \sqrt{\frac{S}{\pi}} \quad (13)$$

where:
S – the area covered by the restriction [m^2].

As external costs differ from country to country, they must be estimated on a country by country basis, taking into account purchasing power parity. The last stage in the estimate is adjusting the cost by a nation's GDP increase for the year of the analysis.

Conclusions

Urban transport investments benefit city inhabitants. Whether they are addressed to passengers of public or private transport or to transport companies that make deliveries in cities, they aim at reducing the harmful effects of transport on city inhabitants, and on our planet. The measures may be divided into two groups. The first is comprised of measures taken to reduce urban traffic (reduce the number of passenger- or tonne-kilometres); the other includes measures taken to streamline traffic in a city, thus reducing its negative impacts on quality of life for city inhabitants. Estimating the social benefits of implementing urban transport investments is a relatively demanding task. The difficulties stem mainly from lack of knowledge about both current and future traffic flows. The proposed methodology, applying the latest tools, such as the Ricardo-AEA study recommended by the European Commission, may be adapted for any analysis of the social benefits and costs of urban investment projects.

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