

**Street mobility and network accessibility:
towards tools for overcoming barriers to walking amongst older people**

The value of the barrier effect of roads and railways

A literature review

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Abstract

Railways and roads with large traffic levels or speeds are physical and psychological barriers between local communities, an effect usually described as "barrier effect" or "community severance". Due to its intangible nature, this effect does not have a market price, and so, methods of economic valuation are needed to derive its value. This paper reviews the methods proposed in the literature for valuing the barrier effect, including stated preference and revealed preference methods, objective approaches, and benefits transfer. The implications of including the values obtained in cost-benefit analysis are discussed.

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Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

1. Introduction

Transport systems have a number of negative external effects, that is, impacts outside the system and which are not priced in the market. The economic value of these impacts is relevant for public policy, especially for informing decisions about investment in the transport system and pricing policies. Over the years, economists have developed sophisticated methods for assigning monetary values to some of external effects, including congestion, accident risk, noise, air pollution, water pollution and climate change [Mayeres *et al.* 1996, Maibach *et al.* 2007, CE Delft *et al.* 2011].

When comparing with those effects, community severance has been relatively neglected by economists and transport planners [Tate 1997, Read and Cramphorn 2001, James *et al.* 2005, Bradbury *et al.* 2007]. Community severance, also known as the barrier effect, is the effect of linear transport infrastructure (such as roads or railways) or road traffic levels or speeds as a physical or psychological barrier separating local communities. The issue has become more relevant in the context of current trends in public policy, with increased attention being given to relationships such as those between walking mobility, health and social cohesion, and between accessibility and social inclusion. Nevertheless, the assessment of severance still relies on ad-hoc procedures or on subjective qualitative scales.

The valuation of severance is difficult because in general it is difficult to assign values to the benefits and costs associated with walking. The task is especially problematic when severance leads to trip suppression, as it requires the understanding of the complex set of psychological and social aspects that shape individual travel behaviour. These limitations may explain the fact that severance effects are seldom given a monetary value in transport project appraisal. For example, in the UK, severance is classified as an impact that is currently not feasible to monetise [UK DfT 2014a, p.2]. Methods for the calculation of the value of severance were included in official guidance for transport appraisal in Denmark and Sweden. In Denmark, the effect was valued at 50% of the value of the noise effect [Vejdirektoratet 1992]. In Sweden, the values used for the disturbance effects of crossing roads and the effects of travelling along roads depended on the age groups affected, but the value of the delays in crossing roads was

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

assumed to be constant across all groups [Vägverket 1986]. These methods were seldom used in practice and have been discontinued.

Severance effects cannot be considered on an equal footing with other positive and negative effects in project appraisal unless they are converted into monetary units. If the value of severance is not made explicit, the effect may be downplayed in the appraisal because, as an intangible effect not traded in the market, its implicit value appears to be zero [Handy 2003, p.139, Pearce *et al.* 2006, p.31]. Ultimately, the problem can be addressed only by knowing the value people attach to it in relation of the costs of solving it. Measuring levels of severance is not enough, because its value may not vary linearly with variables such as traffic levels and speeds or distance between roads and homes.

Severance is a non-marketed 'bad' so methods of economic valuation are usually needed to determine its monetary value. Héran (2011a, Ch.11) suggested that there is a supply and demand for crossing a road. The value of crossing could be determined by assuming that the supply is fixed and the demand for crossings depends negatively of their generalised cost, which includes the monetary cost of walking and the costs of additional energy spent for crossings not at-grade, time losses due to delays and detours, and the disamenity effect. Although theoretically interesting, this proposal is difficult to apply, so in practice, methods of economic valuation are needed.

This paper is a review of methods for the valuation of severance and complements the review in the previous working paper of this series, which deals with methods to identify and measure severance. Section 2 and Section 3 cover stated and revealed preference methods to value severance. Section 4 covers methods which are not based on people's preferences, such as objective approaches and benefits transfer. Section 5 discusses issues related to the integration of these methods in Cost Benefit Analysis. Section 6 concludes the paper.

2. Stated preferences

Stated preference methods use surveys to ask people's choices among hypothetical alternatives. These choices are modelled, in order to assess individual preferences for attributes or packages of attributes, controlling for the participants' characteristics and

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

usual attitudes and behaviour. The preferences are estimated in terms of willingness to pay for or accept marginal changes in the attributes. Stated preference has been used extensively in the estimation of local environmental impacts of transport. A recent review documents the existing research for the case of noise [Bristow *et al.* 2014].

Contingent valuation is a stated preference method in which participants are asked about their willingness to pay for or accept a hypothetical policy affecting the provision of some good or service. Soguel (1995) used this method to assess the cost of severance in Neuchâtel (Switzerland). It was assumed that the effect was removed through the construction of a tunnel, assuming traffic and parking conditions were unchanged. The participants' maximum willingness to pay was determined by an open-ended question, followed by a bidding game. A valuation function was then estimated relating the bids to income, age, car ownership and level and perception of noise exposure. Grudemo *et al.* (2002) also used contingent valuation with binary choices to derive the willingness to pay to bury roads and railways that restrict access to recreational spaces, and Maddison and Mourato (2001) used payment cards to elicit values for changes in the layout of a road that restricts access to a site with cultural value (Stonehenge).

Choice modelling is another stated preference method, which asks participants to choose from alternatives defined by several attributes, one of them defining the payment of compensation associated with each alternative. Choices are then related with attribute levels and the characteristics of the participants using statistical models, from which willingness to pay can be derived.

In the case of the study of community severance, the choices can be between different types of mitigation measures for severance, or between reduction of severance and other neighbourhood investments or changes [Box 1]. For example, Grisolia and López (2011) estimated the willingness to pay for burying a road in the Canary Islands (Spain) taking into consideration the cost of the project and the types of land use on the surface. In the UK, Garrod *et al.* (2002) estimated willingness to pay for traffic calming measures in terms of reductions in traffic speed, noise and community severance (measured by the time to cross the road). ITS and Atkins (2011) also estimated the value of policies that give different levels of priority to pedestrians (shared space, limited vehicle access, or full pedestrianisation).

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

Box 1: Attributes and control variables in choice modelling studies

Study	Attributes	Control variables
Garrod <i>et al.</i> (2002)	<ul style="list-style-type: none"> ▪ Noise ▪ Speed ▪ Beauty ▪ Wait 	<ul style="list-style-type: none"> ▪ Distance x Noise ▪ Distance x Speed ▪ Distance x Beauty ▪ Visible x Beauty ▪ Audible x Noise
Grisolía and López (2011)	<ul style="list-style-type: none"> ▪ Road on surface ▪ Road buried and ▪ Paved square ▪ Garden ▪ Street furniture ▪ CCTV 	<ul style="list-style-type: none"> ▪ High Income x Price ▪ Education x Furniture ▪ Young x Furniture ▪ Old x Surveillance
ITS and Atkins (2011)	<ul style="list-style-type: none"> ▪ Pedestrian priority ▪ Activities for pedestrians ▪ Kerbs ▪ Surfacing ▪ Lighting/furniture 	-

Stated preference methods can also be used to model people's perceptions and behavioural responses to different types and levels of severance. Meltofte and Nørby (2012, 2013) used choice modelling in a survey in Denmark to derive people's trade-off values between number of lanes; traffic volume, composition and speed; and distance to the nearest crossing facility. A proposal was made by Read and Cramphorn (2001, Ch.4) for applying a similar method in New Zealand, but it was never implemented.

One of the challenges in using stated preference methods to value severance is to make sure that participants understand the attributes presented. This issue is usually addressed in the surveys by including images of different road designs and traffic conditions. However, images cannot transmit depth, time and non-visual stimuli, so it is difficult to capture aspects such as traffic speed, visibility, noise and dust. The scope for representing a varied set of non-collinear attributes may also be limited, even when using computer-generated images. Some authors have also mentioned that surveys tend to underestimate the cost of severance because participants do not relate barriers to mobility with their wider impacts [Héran 2000, 2011a, p.160] and do not consider the actual political and social context of the proposals presented [Stanley and Rattray 1978, p.146].

The validity of the participants' choices is another issue in stated preference methods. Participants may be sensitive to the payment vehicle (the way they are expected to pay or

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

receive compensation for the change in question). Participants may also hide their true willingness to pay (strategic behaviour) or refuse to pay any amount (protest answers). The amount people are willing to pay may also be different from the amount they would be willing to accept compensation. Familiarity with the choice scenario also influences choices. For example, in an empirical study of traffic calming schemes, Boeri *et al.* (2014) found that participants who were unfamiliar with the scenario tended to minimize regret, rather than maximize utility (which is the hypothesis of most of the stated preference studies). This may be explained by the participants' concern regarding vulnerable dependents such as young children or older people.

3. Revealed preferences

Revealed preference methods derive people's willingness to pay by observing their choices in markets that act as surrogates for the good, service or policy change studied. In the hedonic pricing method, the hypothesis is that the price of a market good incorporates the values of a set of both tangible and intangible attributes. Choices in this market express individual's preferences for these attributes. The implicit value of each attribute can be determined by estimating a model relating price and the levels of those attributes.

The value of severance may be reflected in the housing market. For example, Kang and Cervero (2009) used hedonic models to estimate the effects on land values of a project in Seoul that demolished a busy urban motorway and replaced it with a stream and a park. Lee and Sohn (2014) estimated the benefits of projects in the same city to replace elevated and at-grade railways with underground subways. Similar approaches were used to estimate the impact of traffic on residential values, using variables such as traffic levels and compositions [Kawamura and Mahajan 2005, Li and Saphores 2012]. Bretherton *et al.* (2000) also estimated the value of traffic calming measures.

There are also a large number of hedonic studies valuing aspects related with severance, such as roadside noise (reviewed in Nelson 2010) and neighbourhood walkability (reviewed in Bartholomew and Ewing 2011). The studies valuing walkability in terms of street connectivity are particularly relevant [Song and Quercia 2008, Matthews

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

and Turnbull 2007]. The value of the visual impact of roads may also be an indicator for psychological severance [Bateman *et al.* 2001, Part 8.5.1].

Hedonic models are notorious for being difficult to estimate. One of the main problems is that attributes tend to be correlated, leading to multicollinearity in the model, and unreliability in the values obtained for each attribute. That is a problem with models valuing severance, as the variable used to measure this effect is inevitably correlated with variables measuring other negative effects of transport, such as noise. It is also difficult to delimit the extent of the relevant market to value severance, that is, the set of properties considered by households.

Conceptually, the models also suffer from the fact that people may not be aware of the problem or not consider it as relevant, and that housing markets may not capitalize severance effects. Finally, while hedonic models can value attributes, they cannot assess the motivations for the choices of levels of those attributes, limiting the understanding of the impact of severance in the households' residence location decisions.

Revealed preference methods other than hedonic models have been proposed and applied in the literature to value local environmental impacts. The averting behaviour (or defensive expenditures) approach consider that individuals show their valuations of a negative intangible effect by finding alternatives to satisfy the needs that are left unfulfilled due to the effect, or by purchasing goods to protect themselves from that effect [Pearce *et al.* 2006, Ch.7.4]. For example, expenditures on double-glazed windows are an indicator of the economic value of noise. This kind of approach is of difficult application on the case of severance, as the averting behaviours (for example, the reduction on the amount of walking or the change in walking routes) are also non-market goods. In this case, the method would require a second step, to determine the economic value of these behaviours. Moreover, it is difficult to isolate the link between severance and averting behaviour, as changes in walking may be due to other personal and environmental factors.

A possible alternative is to consider the financial cost of building or improving crossing facilities or traffic calming solutions as the benefits of reducing severance, but this approach does not fit well with cost-benefit analysis, as it assigns the same value to the benefits and to the costs of the project.

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

4. Beyond preferences

The use of values based on people's preferences has some limitations. Individuals may not be fully aware of the problem or its consequences, or not perceive small or complex changes. Preferences may also be endogenous, that is, formed by the social context [Elster 1983]. A community may have lived with the problems caused by severance for such a long time that they are perceived as inevitable. It is also difficult to account for altruism, that is, the value of reducing severance for people who are not affected directly by the problem. The formation of individual preferences has always been a controversial topic in Economics, as it depends on personal history, culture, and ethics, aspects which are not malleable to quantification.

Studies of people's preferences for severance may also find unexpected results. For example, Stanley and Rattray (1978, p.146) quote a study where the majority of participants preferred the removal of severance to any monetary compensation. In other words, people may not be willing to trade off social wellbeing for economic wellbeing. On the other hand, severance can also have positive aspects [Loir and Icher 1983, p.13]. Natural barriers such as rivers and canals may have an amenity value. The increase in gated communities and cul-de-sacs are evidence that there is also a "demand for severance" [Handy 2003]. A study by Asabere (1990) in an American city confirmed that properties in cul-de-sacs attracted premium values over similar properties in other streets. The phenomenon of "alley-gating" also indicates that the loss of the connectivity of local street network may be desired by a community because it reduces other problems considered as more important, such as crime, anti-social behaviour and fly-tipping.

4.1. Objective values

Objective valuations can be used as an alternative to preference-based methods. Severance has consequences for the economic, social and health wellbeing of the individuals affected. Due to the influence on the choice between non-motorised and motorised transport modes, it also affects variables at the societal level, such as the vitality of local businesses, traffic congestion, pollution and use of non-renewable

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

resources. Some of these individual and social impacts may be linked to market goods, the value of which can be used as a proxy for the value of severance.

The economic value of time losses to pedestrians has been used often as a proxy for the value of severance. For example, Chang *et al.* (2014) gives an alternative method to estimate the value of the project to bury railways in Seoul which was mentioned in the previous section. The formula used is based on the reduction of time in each crossing, the current number of pedestrians crossing and a value of walking time imported from another study. The official guidance for transport appraisal in Germany uses a similar approach [BMVBW 2003, Part IIIb; Gühnemann 2013].

The value of impacts of transport projects on physical activity is also included in the guidance for appraisal in several countries, such as the UK [UK DfT 2014b, Ch.3, 2014d]. Reviews of existing methods to value health benefits of walking and cycling have revealed a lack of standardisation [Cavill *et al.* 2008], although several countries now use the World Health Organisation's HEAT (health economic assessment tool) [WHO 2011]. A number of local authorities, universities and other institutions around the world have also designed tools for measuring the benefits of walking and other physical activity, a number of which are based online. A future working paper in these series will review these tools. Overall, the major limitation of this kind of methods is how to build a “dose-response function” that isolates the link between severance and short and long-term health effects, among other confounding transport and non-transport, local and non-local, individual and social factors.

A more detailed assessment of the effects of severance was proposed by Sælensminde (2002, Ch.7; 2004, Ch.5), as a part of a project to value the external costs of transport in Switzerland. The value of severance was defined as the loss due to the non-realised benefit of a “natural amount” of walking and cycling due to road traffic, taking into account diseases, work absences, school children transport, and parking costs for employers.

4.2. Benefits transfer

The results of valuation studies can also be applied in different contexts, a practice known as benefits transfer. In a study to estimate the external costs of transport in

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

Switzerland, [Ecoplan/INFRAS 2008], a survey was used to calculate the number of road and rail crossings per person per day, considering road and railway width and number of lanes or tracks. This data was combined with the average time loss per crossing and a fixed value of time. The values were then transferred to other cities, corrected by population size, and extrapolated for the whole country.

Despite the gains in terms of objectivity and simplicity, the suitability of this kind of methods depends on the similarity of the levels and nature of severance, characteristics of the population affected and the geographic, social and political context in each place. The values that are imported need to be adjusted to take into account these variables. As alternative, functions relating the value of severance with those variables can be imported from the original study or estimated based on meta-analyses of several studies.

5. Severance and cost-benefit analysis

The main purpose of determining the value of severance is to integrate it in the appraisal of transport projects. Appraisal is the systematic assessment of the positive and negative effects of projects, to determine whether they are worth undertaking.

The appraisal of new transport infrastructure or large-scale schemes to redesign existing infrastructure is usually done using cost-benefit analysis (CBA). This method compares the benefits and costs of a project, expressed in monetary units. This comparison is especially relevant in the case of schemes to mitigate severance, as the benefits may not be enough to justify the financial costs of the intervention and the loss in the benefits that the roads and railways bring to their users and to the communities they cross. For example, Héran and Darbera (2006) give the example of a project for burying a road in France, where the estimated benefits in terms of reduced severance were negligible, as the time gains for pedestrians were only 20 seconds.

CBA is usually not required in the case of smaller projects such as street redesign (giving more space to pedestrians or improving the street environment) or traffic policies (like the reduction of speed limits). However, the estimation of the benefits of these projects and their comparison with their direct and indirect costs is important as in some

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

circumstances projects to reduce severance have undesirable side-effects such decreasing safety [Lerväg 1984, Ch.3].

A common criticism of CBA is that the method judges whether overall a project is an efficient allocation of resources to meet needs, and as such, they do not address issues of equity. In addition, the use of monetary values may introduce bias because if we assume that marginal utilities of income decrease with income, then people's willingness to pay for a non-market good depend on their ability to pay. Theoretically, these issues can be integrated in CBA by assigning different weights to the benefits and costs of some groups [Pearce *et al.* 2006, Ch.15]. In practice, distributional issues are usually accounted for in project appraisal by separating and using different methods to measure the impacts on vulnerable groups [UK DfT 2014c, Ch.6]. An alternative is to weight the impacts of the projects according to the groups affected. For example, the Swedish approach to assess severance [Vägverket 1986] used observed trip frequencies to measure the potential need for walking for each age group, which in the case of elderly people were corrected to account for higher propensity to suppress trips where barriers already exist.

CBA requires the estimation of benefits and costs occurring in the future, and their translation into present values. This task can be problematic in the case of the accounting of severance costs. There is a high degree of uncertainty regarding future effects, as they depend on changes in the local population, transport infrastructure and traffic characteristics, and types of land use. In addition, people's perceptions of the problem also change over time [Lee and Tagg 1976, Appleyard *et al.* 1981, p.39, Loir and Icher 1983, p.30, 38].

There are also issues related to the inclusion of severance along other items in CBA. Travel time tends to dominate the monetised costs and benefits of most projects [Mackie and Worsley 2013, p.6] but there is no consensus on issues such as the accounting of small time savings, the differences between gains and losses, and the disaggregation of values for different groups, for non-motorised and motorised trips, and for working and non-working time. It is also difficult to disentangle the values of severance from those of other nuisances of transport such as noise, pollution, safety and amenity. In general, people tend to disregard severance as compared to the more tangible effects [Smith and

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

Gurney 1992, p.15] and might in fact be implicitly valuing those other effects in stated preference surveys about severance [Soguel 1995, p.306]. There is therefore a risk of double counting, that is, of assigning to severance the value already assigned to another item [Héran 2011b].

The reduction of a complex problem such as community severance to a monetary value also carries some risks. Tomlinson and James (2005, p.10) suggest this is the reason why countries such as Sweden and Denmark abandoned formulae for the detailed assessment of severance. Nevertheless, the tendency in several countries has been to move in the direction of the monetisation of transport's external effects [Mackie and Worsley 2013, p.6]. Progress in transport and environmental economics research may provide solutions for solving the issues identified in this review regarding the valuation of severance. The risks of reductionism can also be addressed by the construction of multidimensional indices, disaggregated according to different aspects of the problem, or to the group affected, and allowing for sensitivity tests on each dimension.

6. Conclusions and scope for further research

This paper reviewed methods for the economic valuation of community severance caused by transport infrastructure and traffic. In most countries, severance is not given a monetary value in transport appraisal. Old versions of official guidance documents for transport appraisal in countries such as Sweden and Denmark included methods for the valuation of severance, but these methods were seldom used and do not figure in the current versions of those documents. However, academic research on the value of severance has increased in recent years, including stated preference and revealed preference methods, and approaches that are not based on preferences, such as benefits transfer and the measurement of the value of market goods associated with aspects of severance. These efforts have helped the assessment of severance to move beyond qualitative evidence, although none of the methods have been adopted as routine practice for transport professionals.

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

This review shows that researchers have mainly focused on the value of specific problems caused by severance (especially the time losses for pedestrians), or on the value of general solutions for those problems (for example, burying roads). There is little evidence on people's trade-off values between different problems or different solutions. Héran (2011a, p.168-169) enumerates some of the aspects that have been neglected: time losses for cyclists, time losses for people accompanying people with mobility restrictions, the extra energy spent to cross a road, the space used by the road and effects on social interaction, modal shift (from walking to private vehicles) and land use patterns. In general, the valuation of severance must consider attributes related to infrastructure, road traffic, crossing facilities and street environment. The estimation of the values of these attributes must also consider differences in individual characteristics, spatial context and time of day.

The existing research has also produced little evidence on types of severance other than the effects of road infrastructure and traffic on pedestrians. Railway-based severance is different as the number of pedestrian crossings is limited, crossing is not at-grade and safety issues are less relevant. Road infrastructure may also have negative effects on the circulation of cyclists and even on motorised traffic. This last case occurs when the presence of large transport infrastructure restricts the exit of vehicles from neighbourhoods which have a small number of exits [Rajé 2004, Héran 2011a, p.31].

There is also scope for the adaptation of methods that have been used to value aspects related to severance, such as accessibility, walkability, pedestrian safety, exposure to noise, and the visual blight of roads. However, a clearer definition of severance is needed. The issue has been approached by researchers from different disciplines, focusing on different aspects of the problem. Due to insufficient dissemination of research, different understandings of severance have developed over the years even within the same discipline. The challenge for economists is to find the best set of attributes to be valued, among the multiplicity of attributes that have been suggested in existing literature. The choice of this set should not be based only on theory because, as a complex and multidimensional issue, community severance is perceived differently in each case study area. Input from the communities affected by the problem is needed prior to the specification of surveys and statistical models.

Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

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Street mobility and network accessibility: towards tools for overcoming barriers to walking amongst older people

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