Title:

Need for a holistic assessment of urban mobility measures – Review of existing methods and design of a simplified approach

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Abstract

The lack of suitable tools to assess sustainable mobility measures’ costs, benefits and overall impacts is a significant factor impeding their implementation. Current practices in transport project appraisal differ largely between cities across Europe. Cost-benefit analysis (CBA) is often applied to large-scale infrastructure projects, but does not capture all relevant – especially small-scale – local impacts well. Small but innovative concepts often do not have the critical mass to warrant a thorough cost-benefit analysis. A simplified appraisal tool that assesses all aspects of a policy or measure, and is applicable to a variety of urban mobility interventions does not exist, or has not found widespread use.

This paper reviews existing assessment methodologies, including their advantages, limitations and application to different urban mobility measures, and current assessment practice in cities based on survey results. Based on these analyses, a holistic approach for
project appraisal is proposed, consisting of aspects of a multi-criteria analysis (MCA) and CBA methods and applicable to a variety of urban mobility measures.

**Keywords:** cost benefit analysis, multi-criteria analysis, impact assessment, urban transport,
1 Introduction

Planning and managing urban transport systems is often a difficult undertaking for local administrations tasked with doing so. A reliable urban transport system is crucial to a functioning local economy, as it provides access to services and enables personal mobility (Browne and Ryan, 2011). At the same time, high levels of traffic impose negative externalities on society, including congestion, accidents, noise pollution or environmental damage (Santos et al., 2010). Thus, decision-makers must consider a variety of different impacts (economic, social and environmental) resulting from urban transport projects or measures, along with their objectives. Investments in urban transport should deliver the maximum economic, social and environmental benefits possible; in times of constrained budgets, projects’ economic viability is often the deciding factor. Thus, decision-makers need information on the potential costs, benefits and overall impacts of urban transport measures or projects.

The concept of evidence-based decision-making is intended to help policy-makers to maximise the benefits from their investments, and to prevent investments in measures or projects that fail to address critical problems, by basing decisions on ex-ante assessment of measures’ potential effects ideally in all relevant fields. Small-scale sustainability measures might profit in particular from such an assessment, as their inherent costs and benefits can become more explicit. Including all factors that determine the sustainability of an urban transport system into assessments can promote the implementation of soft measure or innovative projects, whose implementation is often impeded by decision-makers’ tendency to assess measures more narrowly, which favours traditional measures such as road expansion which promise short-term congestion relief, but often do not address wider sustainability concerns well or at all.

This paper assesses the question of how cities can assess the costs, benefits and overall impacts of urban transport projects and measures on an ex-ante basis to allow sound decision-making. To answer this research question, firstly, the advantages and limitations of the most commonly used methods to appraise transport projects are analysed, especially the cost-benefit analysis (CBA) method; frequently applied to large-scale infrastructure projects, and multi-criteria analysis (MCA), often seen as an alternative to a CBA (Beria et al., 2012). Secondly, examples of the methods’ application, for both the ex-ante and ex-post assessment of various urban transport measures from an extensive review of scientific literature and complementary selected examples from grey literature are presented. Thirdly, the current practice for ex-ante impact-assessment amongst European cities is examined, based on a written survey of 14 cities, conducted in the course of an EC FP7 project. Insights
from the survey are complemented by literature analysis. Based on the overall analysis, a new approach for a holistic impact-assessment method was designed, which should better reflect cities’ needs and be better applicable to the diverse range of urban mobility measures.

2 Analysis of existing assessment approaches and their application

This section contains an introduction to the two widely used assessment methods and advantages and limitations. Subsequently, examples various measures’ assessments are presented, followed by an overview of assessment practice throughout Europe.

2.1 Common assessment approaches

Cost-benefit analysis (CBA) and multi-criteria analysis (MCA) are common methods used for the ex-ante or ex-post evaluation of transport projects or measures (Beria et al., 2012); selected here for detailed analysis. Other approaches such as cost-effectiveness analysis, designed to identify the lowest-cost option to achieve a specific objective, or environmental impact assessment have not been included, as they focus on only a selected set of impact factors rather than all of a project’s or measure’s impacts (Browne and Ryan, 2011).

Cost-benefit analysis

The idea of a CBA is to express all of a project’s or measure’s impacts, direct and indirect, in monetary terms, allowing the economic viability of a project to be assessed and expressed by viability indicators such as benefit to cost ratio (BCR), internal rate of return (IRR) or net present value (NPV). Impacts already expressed in monetary terms, such as investment or operative costs can be included easily in a CBA, whereas those impacts expressed in non-monetary terms must be monetised. Some of these impacts have a direct market value, such as travel times or material damage caused by accidents. Otherwise, non-monetary impacts may be monetised by determining a monetisation factor for them, for which many techniques are available (Tudela et al., 2006).

One of the main advantages of the CBA method is the ease in communicating its results through one or more indictors (Browne and Ryan, 2011). A project can be easily accepted or rejected based on the NPV (which indicates whether the benefits exceed the costs). Also, by comparing the BCR of two alternative projects, the project that yields the higher benefits for each Euro spend can easily be identified. Especially in times of constrained local-government budgets, a project’s economic efficiency is important to local decision-makers. The limitations of the method arise mainly from the monetisation of non-monetary effects, as it is questionable if all impacts can be appropriately reflected in monetary terms. Also, there
is uncertainty about the robustness of the results of non-market valuation techniques (Bickel et al., 2006), while monetisation factors can vary significantly from place to place, although some effort has been made to improve the robustness and comparability of monetisation factors (e.g. Bickel et al., 2006). Especially less-tangible impacts such as comfort or quality of life are difficult to monetise and thus often neglected or ignored in CBAs. Furthermore, ethical questions are raised by assigning monetary values to certain factors such as road fatalities (Beria et al., 2012). Another criticism of the method is that travel time savings are usually among the dominating factors, but the fact that these savings can lead to side effects, such as longer or more frequent trips, is neglected. Finally, CBAs also have the disadvantage of extensive data requirements: all effects must be quantified and monetised (Browne and Ryan, 2011).

**Multi-criteria analysis**

The MCA method involves assessing measures in a two step process. Firstly, a set of criteria is developed by which the measures should be assessed, and these are each assigned a weighting value, reflecting the relative importance of each of the criteria (Browne and Ryan, 2011). Secondly, the performance of the measure and alternatives is assessed, in either qualitative or quantitative terms. Combining the criteria scores and their weights and adding them together results in an overall score for each measure, indicating it’s relative appropriateness (according to the assessment criteria). There are various approaches to assign the criteria weights and combine the scores and weights to yield an overall score (Beria et al., 2012), but a commonly used one is the Analytic Hierarchy Process (AHP), developed by Saaty (1977).

The main advantage of the MCA method is that a variety of factors can be included, even if they are difficult to quantify or monetise, and as such, it allows the evaluation to be more holistic (Beria et al., 2012; Browne and Ryan, 2011). The process by which scores and weights are assigned are seen, however, as both an advantage and disadvantage of the method. On the positive side, the scores can be based on experts’ estimates (limiting the amount of work required for the assessment), while the criteria weights can be assigned through participatory processes. Browne and Ryan (2011) see in the stakeholder involvement in a MCA a potential to contribute to resolving interest-conflicts. Similarly, Tudela et al. (2006), praise the possibility of including public opinion. On the negative side, these processes are subjective, negatively affecting the results (Beria et al., 2012). Furthermore, participatory processes can be very resource intensive (Browne and Ryan, 2011).
2.2 Application to urban mobility policies and measures

A huge variety of measures or projects is available regarding the planning and management of urban transport systems, ranging from major infrastructure projects to small information campaigns, with an accordingly diverse range of costs and benefits, both in type and magnitude. Thus, the applicability of assessment methods depends on the measure or project being assessed. In the following, the application of CBA and MCA to different urban transport policies or measures is investigated, based on a selection of examples of – ex-ante and ex-post – assessments from the literature. This investigation can only reflect a small proportion of measures, and is subject to the limitations imposed by the non-publication of many analyses. A critique of the various case studies, such as of their evidence base, indicators considered and methodological consistency cannot be provided here. However, this investigation can provide some insight into the application of the assessment methods for the various kinds of measures. Ex-ante as well as ex-post assessments were included in the analysis.

A measure commonly assessed by CBA is urban congestion charging. Examples are manifold. CBAs for the London congestion charge were conducted by Prud’homme and Bocarejo (2005), and by Transport for London (2007), while the Stockholm congestion charging scheme was analysed in a CBA by Transek (2006) and Eliasson (2009). Also, Milan’s Ecopass scheme was evaluated by Rotaris et al. (2010). Finally, in their review of CBAs themselves, Raux et al. (2012) reviewed the CBAs conducted for Stockholm and London, highlighting some methodological problems, such as the way travel time savings and their sensitivity were calculated, and the way indirect effects were assessed. Even though the studies investigated quite similar measures, the impact criteria used in their assessments vary. In general, however, indirect effects on pedestrians, cyclists or public transport passengers are not included in CBAs, while the dominant benefits are often time savings for individual motorised transport (Raux et al., 2012).

For measures addressing walking and cycling, mainly infrastructural measures have been assessed with a CBA. Sælensminde (2004), investigated the cost and benefits of the expansion of walking and cycling paths in three Norwegian cities. Examples from the USA include an ex-ante CBA for footpath construction in Dane County, Wisconsin by Guo and Gandavaramapu (2010), and a CBA for cycling investments in Portland, Oregon (Gotschi, 2011). Based on a review of 16 economic analyses of cycling and walking infrastructure, Cavill et al. (2008) found that the underlying assumptions differed significantly between the 16 studies, as did the criteria assessed. Several assessments in the field of walking and cycling focus on, or limit their investigations to health benefits (e.g. Gotschi, 2011). In several
countries, HEAT (Health Economic Assessment Tool), developed by the World Health Organisation, is used to assess the economic benefits of walking and cycling (Kahlmeier et al., 2010). In the ex-ante assessment conducted by Sælensminde (2004), the projected effect on cyclist numbers of a package of measures supporting cycling – such as bicycle parking facilities and safer crossings. This might be typical for such cycling assessment, as single, stand-alone project might not achieve significant effects. However, it is essential to ensure that the costs for such additional measures are as well included in the appraisal.

For some measures, impact studies are available, but no CBA or MCA. Bus priority systems using intelligent traffic lights, for instance, were evaluated in several cities for their impact on travel time and reliability (Gardner et al., 2009), however, in the cases found, no overall appraisal was conducted. Soft measures like improving traveller information are usually not covered by impact assessments at all: no MCAs or CBAs in this field could be identified in the literature.

More examples of CBAs are provided by the EC-funded CIVITAS project, for which many of its measures were evaluated with CBAs. The measures include alternative fuels for public transport and car sharing or pooling initiatives, however, for some measures no CBA could be conducted due lack of a clear reference case, limited or inconsistent data (Piao et al., 2010).

The examples of appraisals available in the literature indicate that CBA is mainly applied to infrastructure projects – including infrastructure for non-motorised modes – and to projects intended to generate revenue such as city tolls. However, the exact design and the impact criteria included in the assessment vary between measures as well as between studies of the same measure, greatly limiting the comparability of the results. Communicating only overall results, summarised for instance into a BCR, carries with it the risk of non-assessed impact factors being neglected in the decision-making process, and that of BCRs of different studies being compared despite resulting from assessments with different assumptions and criteria.

2.3 Current application in research and by transport practitioners
After having reviewed the way in which specific urban mobility measures are assessed, now the way in which the methods are embedded and applied in the decision-making process in cities will be examined. CBA is frequently used in decision-making for road and rail infrastructure: Odgaard (2006) found that 9 of 26 European countries use MCAs in road project appraisal, while all countries surveyed used CBA. However, a CBA is sometimes complemented with an MCA to allow appraisal of criteria that are not monetised (Bristow and
Nellthorp, 2000; Odgaard et al., 2006), although the exact approaches used and the
indicators assessed vary between the countries (ibid.). In many countries in the EU, CBA and
MCA are prescribed by the national appraisal framework for transport infrastructure projects;
some have national appraisal guidelines, mandatory for major infrastructural investments
eligible for public funding, such as the WebTAG tool in the UK and the OEI in the
Netherlands; reviewed by Annema et al., (2007) and Geurs et al., (2009). Geurs et al. (2009),
criticises both, noting that, even though the UK WebTAG performs slightly better than the
Dutch guidelines, neither cover the full range of potential social impacts stemming from a
transport measure. In addition to being a requirement for funding, the UK WebTAG
guidelines are also intended to serve as best-practice for the assessment of other transport
projects. As they were primarily developed for nationally-relevant projects, the appraisal
guidelines pay little attention to local effects (Geurs et al., 2009), and thus may not properly
reflect cities’ objectives. Similar to the national frameworks, the EC Directorate-General
Regional Policy has developed a common guideline for cost-benefit analyses (required for
funding), including a specific section on transport projects. However, this primarily focuses on
larger transport projects: depending on the fund, a CBA is required only for projects with a
volume of €10m or more. MCA is recommended as a complementary tool where
monetisation is difficult or impossible (EC DG Regional Policy, 2008).

Besides large infrastructure projects, there are a variety of urban transport measures
implemented by cities which are not directly affected by national guidelines or funding
guidelines. Insights into the actual assessment practice in cities across Europe have been
obtained from survey of 14 European cities. Although the survey is not representative, it
nevertheless contains results from cities of various sizes (ranging from ≈50,000 to ≈2.7m
inhabitants) and from 10 different countries across Europe. The results may also be
influenced by the respondents’ various roles and positions within the local administration.
The qualitative analysis revealed that the cities usually do not have a standard appraisal
method for all transport projects, while some cities stated that they select or adopt a method
depending on the measure being assessed. In line with the results from the literature, CBAs
are often applied for larger infrastructure projects in the cities; several respondents referred
to national regulations requiring them to do so. For instance, in Italy a CBA is “the ordinary
tool for projects above €10m and mandatory for projects above €50m”. Several other cities
referred to national guidelines on the CBA method and cases to which it must be applied.

Additionally, some cities also use MCAs in their project appraisal. The survey’s British
participant city highlighted the importance of the WebTAG tool, and mentioned that although
smaller schemes can be assessed in a simpler way, “there would need to be a very good justification for not following the guidelines”.

Although many projects are not subject to a cost-benefit analyses as such, financial viability checks are nevertheless of major importance, although, according to the survey, economic viability is not necessarily the decisive factor in transport decision-making. Cities mentioned that “local issues”, “the service offered to the citizens” and “impacts which cannot be quantified” can balance or dominate the CBA results. Further, the cities were asked about the challenges presented in carrying out a CBA: issues like “the monetisation of qualitative externalities and not-clear impacts”, “putting value on all the externalities”, “lack of statistical and traffic data”, “[lack of] evidence base for … small schemes and soft measures” and “lack of standard guidelines” were mentioned. It can be concluded that especially the quantitative and monetary basis of a CBA is challenging for a city and limits the method’s applicability to local projects.

The analysis of existing assessment practices reveals that, especially for non-infrastructure measures, there is a lack of a standardised assessment approach in most cities. Additionally, the assessment of infrastructural measures – often with CBA – varies significantly in terms of the criteria assessed, including those that are difficult or impossible to monetise and thus often neglected/ignored.

3 A holistic but simplified assessment approach for local mobility measures

Based on the analysis presented in Section 2, the authors concluded that there is a need for a simple (i.e. the effort required is not excessive compared to the magnitude of the measure itself), but holistic (i.e. including all factors) assessment approach that can be applied to a variety of urban transport measures. The approach suggested here is primarily based on the MCA method, but also allows the integration of CBA aspects if required and if sufficient data is available. A step-by-step guide addressing local practitioners is currently under publication (Hüging et al. undated). Table 1 provides an overview of the assessment steps. However, note that the following outlines only the key characteristics of the approach.

Table 1 Steps of the suggested assessment approach for cities (Hüging et al. undated)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
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<tbody>
<tr>
<td>1. Describe project and alternatives</td>
<td>The planned project and alternatives, including the reference (BAU) case are described. The assessment details (e.g. appraisal period) are determined.</td>
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<tr>
<td><strong>2. Identify effects and indicators.</strong></td>
<td>The effects by which measures should be assessed, along with the indicators by which the performance should be measured, are identified.</td>
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<tr>
<td><strong>3. Impact assessment.</strong></td>
<td>For BAU and the proposed project (and any alternatives), the magnitude of each of the effects selected in step 2 is determined.</td>
</tr>
<tr>
<td><strong>4. Normalisation</strong></td>
<td>The performance figures are converted to unitless, relative numbers.</td>
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<tr>
<td><strong>5. Criterion weighting</strong></td>
<td>The criteria are assigned a weight value reflecting their relative importance.</td>
</tr>
<tr>
<td><strong>6. Visualisation and interpretation</strong></td>
<td>Final scores for each measure are calculated from the normalised performance and weighting value, which can be displayed in graphs.</td>
</tr>
<tr>
<td><strong>7. Sensitivity analysis.</strong></td>
<td>The significance of individual effects is assessed to test the effect of less-reliable assumptions/values.</td>
</tr>
<tr>
<td><strong>8. Communicate results.</strong></td>
<td>The results and key information about the assessment procedure are communicated to the decision makers.</td>
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The approach is designed to compare a measure or project to a reference case or and to a set of alternative measures, primarily ex-ante. A CBA can be conducted, on all criteria for which monetisation is feasible, in parallel within the process, from which economic viability indicators are calculated, like in a conventional CBA. The performance of rest of the criteria can be assessed either quantitatively (non-monetary, e.g. tonnes of NOx) or qualitatively (i.e. expert-based and literature-based scoring). In the overall assessment all criteria will be included, whether there are included in the optional CBA or not.

For the further assessment, all performance figures, including the monetary values, are normalised using a maximum score approach, i.e. Measure A’s score for Criteria 1 (C1) is based on the original performance value \(x_{C1(A)}\) divided by the largest (absolute, i.e. positive or negative) performance value for Criteria 1 \(x_{C1(max)}\) for any of the measures being assessed. To obtain ease to communicate results it is recommended to use a scaling factor \(F_{scale}\) of 10:

\[
Score_{C1(A)} = \frac{x_{C1(A)}}{x_{C1(max)}} \times F_{scale}
\]

This approach was chosen by the authors over a transformation based on a linear function based on the minimum and maximum performance (e.g. van Herwijnen (undated) and Steierwald et al. (2005)), which would require either additional work to determine threshold
values or the inclusion of a larger number of measures from which the threshold values would be obtained.

For the criteria weighing process (step 5) the authors suggest a process based on AHP (Saaty, 1977), with considerable simplifications: the criteria are clustered on a hierarchical basis and a limited, predetermined number of weighting points are allocated to the categories in the first hierarchy level (Figure 1). Those points are then further allocated to the subcategories until the lowest hierarchy level is reached. This relatively simple weighting procedure allows for stakeholder participation without needing to expend significant extra effort. A city might also consider standardising the certain weights according to the cities most pressing need. This could be done with input from the public through an event whereby the weighting values could be allocated to reflect the objectives regarding the city’s transport system which would then be applied to all subsequent assessments.

Figure 1: Simplified illustration of the weighting procedure

Based on the normalised performance scores and the weights, an overall score can be obtained for each alternative measure or the reference case. If a CBA is included in the
process, the economic viability indicators can be communicated to decision-makers together with the overall score. Often, the process of a CBA or MCA or the reflected criteria are not fully communicated to decision-makers or not fully considered in the decision-making process. Because of that, a special emphasis of the suggested approach lies on the communication of results. Besides the overall score and the optional CBA results, the authors suggest communicating the absolute impacts for all criteria in an impact-summary table, similar to the practice in the UK WebTag guidelines.

The suggested approach allows including all effects of a measure and thus enables a holistic assessment. It can be assumed that the possibilities to include impacts in a relative simple qualitative manner will encourage cities to account for effects that are often neglected due to difficulties in quantification or monetisation. In contrast to parallel assessment using both CBA and MCA methodologies, i.e. performing a CBA and evaluating soft effects with an MCA, as suggested by Beria et al., (2012), the approach presented here does not produce conflicting results, as it includes all effects (hard and soft) in the overall score, and can thus be said to be holistic. With the results of this method, it can be clearly communicated to decision-makers that the ‘classic’ economic viability indicators are a valuable result, but that these probably reflect neither all of a measure’s impacts nor the cities overall priorities (as reflected in the weights). The method is designed as open process, enabling stakeholder consultation and public participation. In addition, the results are not limited to a single value, but accompanied by a comprehensive impact summary table, which can improve the understanding of the methods and its relevance in the decision making process.

Another key advantage of this approach is applicability to a variety of urban mobility measures, opening up the possibility of establishing it as the standard assessment, while maintaining CBA as an optional addition. Additionally, the approach is flexible concerning the amount of work required to perform it: minimal for less costly and small-scale measures, probably focussing on qualitative assessment with a greater role for experts’ estimates. For larger-scale or cost-intensive measures, a more intensive assessment including extensive data gathering and modelling can be performed, allowing more criteria to be quantified. It should be noted that the simplification of the weighing process or qualitative performance assessment can increase the approach’s susceptibility to bias, however, these simplifications are seen as prerequisites to allowing cities to conduct the assessment within their own capacities.
Conclusion and outlook

Currently, no standard method of assessing the costs, benefits and overall impacts of urban transport projects exist among European cities. Large-scale infrastructure projects are often assessed using the CBA method, according to national requirements. However, a CBA often does not allow a holistic assessment, and the method is not applicable to a wider set of urban mobility measures. For non-infrastructure local measures, no specific assessment practice exists, however, the MCA method is sometimes applied to these projects. The lack of a more standardized, holistic approach to assessing the costs, benefits and overall impacts of different types of measure may impede the uptake of non-infrastructure measures, which might benefit if such a standardized, holistic assessment approach were applied to proposed transport measures in a city. It is apparent that MCA is more adept at capturing the variety of local impacts of urban mobility measures, thus a simplified assessment approach based on MCA was developed, combining qualitative and quantitative performance evaluation. The suggested approach was designed to be applicable to a variety of urban transport measures – including small scale or low cost measures. It is more holistic than CBA, but can still be complemented by economic viability indicators if necessary.

The next step is to test the applicability of the approach, possibly including case studies on specific measures, as well as the method’s general integration into the assessment and decision-making practice of a sample city. In addition, a systematic review of existing evidence for the impacts of different urban transport measures will be conducted. This could considerably improve expert estimates on specific criteria.
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