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Towards a more equitable distribution of resources: Using activity-based models and subjective well-being measures in transport project evaluation

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ABSTRACT

In this paper, we develop an innovative and comprehensive transport evaluation criterion to better account for equity considerations in transport project evaluation. This work explores transportation benefits from the consumer's perspective to accessibility as a key benefit generated by any transportation project. To assess the full benefits of transportation project implementation for various consumers and calculate the improvement in accessibility, it is best to use Activity-Based Models (ABM). ABMs have two important advantages for equity analysis, which have not been utilized in the literature so far: first, ability to analyze results by various groups of the population; second, these models can utilize the Activity Based Accessibility (ABA) measure to estimate the overall benefits from transport investments and policies. The ABA measure allows one person to have different accessibilities for different choice situations, depending on his/her characteristics. We suggest including social and spatial factors in social welfare assessment by introducing the concept of accessibility gains to key social activities. Specifically, it is suggested to incorporate subjective well-being consideration into a new evaluation framework "Equity Benefit Analysis" (EBA). we use an alternative measure, "Subjective Value of Accessibility gains" (SVOA), which is based on the ABM accessibility measure as well as on Subjective Well-Being (SWB) measure, as the key benefit taken into account in the evaluation process. The SVOA is not intended to replace the current practice of analyzing equity by comparing various impacts on different groups of the population, but can aid by providing policymakers with a single measure advancing both equity and efficiency considerations and facilitating comparison among alternatives. Initial case study results indicate the SVOA can show higher benefits to policies focusing on the needs of vulnerable social groups that compared traditional measures.

1. Introduction

Transportation infrastructure has a massive impact on economic growth and society; it is an important component in the development and growth of a country, and, consequently, the investments in transportation systems are enormous. Two major considerations should guide the evaluation of transport projects: efficiency, a measure of the degree to which system

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outputs achieve a theoretical maximum (minimum) using the same level of inputs, and equity, a measure of the distribution of outputs (or inputs) across the population (Levinson, 2010). However, the most commonly used tool for policy analysis in the transport field is Cost Benefit Analysis (CBA), leading to a focus on efficiency aspects rather than on equity (Rietveld, 2003). Indeed, our review of various transport project appraisals guidelines (see Section 2.2) shows that in the vast majority of cases disparities in society are not taken into account. The key role ascribed to equity in political debates is not reflected in ex ante policy studies in transport.

Equity aspects should be included in a more explicit manner in the evaluation recognizing that in a complex system, like transportation, if the most equitable investment will be made, that is to say, were it is most needed; then, it will produce the most efficient outcomes. However, the integration of equity in economic evaluation involves great complexity, and therefore it is usually neglected despite its great importance (Rietveld, 2003). Complexity is due to several factors: first, there are multiple types of equity; second, there are various ways to categorize people for equity analysis (according to socio-economic status, income level, education, etc.); finally, there are numerous impacts to consider, and various ways of measuring these impacts (Litman, 2002; Nahmias-Biran et al., 2013a).

We explore transportation benefits from the consumer's perspective and suggests a simple framework for the inclusion of social factors in the assessment of transportation projects towards a more equitable distribution of resources. We present a framework of a new measure, the "Subjective Value of Accessibility gains" (SVOA), which takes into account both efficiency and equity considerations, based upon both Cost-Benefit Analysis and Multi-Criteria Analysis. The suggested measure is not intended to replace the current practice of analyzing equity, yet it can provide policymakers with a new measure that promotes both equity and efficiency considerations in comparing among alternatives, shifting the focus in the overall evaluation to the underprivileged sectors of society. The designed measure can take into account the heterogeneity in passenger preferences and their basic level of accessibility, and compensate for the existing bias of traditional evaluation tools in a structured way.

This paper contains four main parts. In Section 2, we present the theoretical background, providing an overview of the three main fields from which this work stems: ethical framework, transportation project evaluation, and transport modeling. Section 3, on the methodology, presents the new framework and its mathematical elaboration. Section 4 includes a case study and a preliminary examination of the new framework. Finally, Section 5 presents the main conclusions and findings of this work.

2. Theoretical background

The following sections comprise a literature review of the key topics of this work: equity considerations, transport project evaluation, and travel demand modeling.

2.1. Ethical frameworks

Justice theories have an expression in practice; any economic evaluation scheme reflects a theory which is the moral justification for the distribution of resources in one way or another. Therefore, a discussion of these theories is essential to the integration of equity considerations into economic evaluation. This topic justifies a complete discussion of its own; see for example Nahmias-Biran et al., 2013b; Martens, 2006; and Van Wee and Geurs, 2011. Yet, the moral justification constitutes a main motivation of this work; therefore, we briefly present theories which are relevant to the methodology presented in this paper.

During the 20th century, the utilitarian approach has prevailed, as it reflects the backbone of welfare economics and CBA (Thomopoulos et al., 2009). According to the utilitarian approach, a society is properly arranged when its institutions maximize the net balance of satisfaction. Utilitarianism has drawn considerable criticism (Rawls, 1986, p. 651), while it does distinct between persons by their willingness to pay, but raises equity issues as discussed in Section 2.2.2

On 1971 Rawls has founded a new intellectual approach that focuses on the basic structure of society. Rawls argued that a just structure implies a distribution of primary social goods according to a well-defined set of principles. He suggested considering the needs of individuals – as opposed to "maximizing the welfare" – the interpretation of society's needs as a whole. Rawls also claimed that we should not favor the majority at the expense of the least well off, and that "Inequalities are permissible when they maximize, or at least all contribute to, the long term expectations of the least fortunate group in society" (Rawls, 1971, p. 60–90).

The greatest strength of the 'Primary Social Goods' approach is that it asserts that there are absolute values - things that matter to all human beings - overcoming the relativism of economics and related preference-based accounts (Dodds, 1997). Rawls suggested that a relatively uncontroversial account of rationality could help us work out the features of the index of these primary goods. Some researchers have suggested that accessibility, a measure of an individual's ability to participate in activities in the environment, could be interpreted as an additional primary good (Martens, 2006; Van Wee and Geurs, 2011). In accordance, Martens (2006) suggested basing economic evaluations on an accessibility measure. In this work, we carry out this theoretical idea and bring it into action. In line with Rawls' approach, we suggest basing transport economic evaluation on both objective and subjective measures.

2.2. Transport project evaluation

2.2.1. Evaluation measures

The evaluation of transportation systems attracts considerable attention in the literature. Different disciplines and traditions approach the problem differently, with unique concerns and objectives (Levinson, 2003).

Accessibility, as calculated in the most fundamental way through micro-economic based tools, is capable of providing an overview on the relationship of transportation, activities, and land use. A large number of studies show that Accessibility is the most strategic and appropriate measure for evaluating the consumer benefits from a transportation project, since it corresponds directly with the perceptions of transportation users (Levinson, 2003; Dong et al., 2006). Having accessibility to a wide number of jobs, shops, medical services, or educational facilities is a value in itself, even if no actual use is made of these destinations, as it increases choice and, thus, future options (Van Wee and Geurs, 2011). This approach draws upon Rawls' Theory of Justice' (1971), which suggested considering the abilities and needs of individuals.

According to economy theory, social welfare gains from economic investments are expressed by a change in consumers' surplus. In the practice of transportation project evaluation, the 'rule of half' provides a good approximation of the change in consumer surplus with limitations regarding projects involving land use changes. There is a large gap between theory and practice regarding the use of consumer surplus in transportation. Theoretically, the generalized travel cost, which is used to calculate the consumer surplus, includes all passengers' direct and indirect travel costs. However, it is very difficult to estimate this cost, and travel time is used as a proxy. As a result, transportation consumers' surplus is based on a mobility measure. This approximation is appropriate only for medium-term evaluation of major investments that have relatively minimal effects on the distribution of land uses, as it ignores the value of opportunities that accessibility aims to measure (Levinson, 2003).

Engineering and economic indicators, as discussed above, can provide limited information; well-being measures can complete the picture and assist policy makers to make better decisions. Well-being is defined as people's evaluations of their lives, encapsulating domains such as life satisfaction and happiness (Diener et al., 2009). Unlike the concept of "utility" in economics, which relates to what people actually do, well-being measures should capture what people could do (Sen, 1985). A large body of empirical literature in economics is focused on understanding the determinants of individual well-being using happiness or subjective well-being (SWB) measures (Mentzakis and Moro, 2009). Part of the literature is devoted to exploring activity happiness (Ettema et al., 2010; Krueger et al., 2008; and Abou-Zeid and Ben-Akiva, 2012), directly tying well-being studies to transportation planning and management.

Recent empirical studies have demonstrated that happiness is affected by activity type and income groups. Csikszentmihalyi and Hunter (2003) used the Experience-Sampling method to examine proximal environmental factors, as well as behaviors and habits that correlate to personal happiness. Jakobsson Bergstad et al. (2011) investigated whether satisfaction with daily travel has a positive impact on SWB. Kahneman et al. (2004) used The Day Reconstruction Method (DRM) to assess how people spend their time and how they experience the various activities and settings of their lives. Kahneman and Krueger (2006) discuss how individuals' responses to subjective well-being questions vary with their circumstances. They argue that it is fruitful to distinguish among different conceptions of utility rather than presume to measure a single unifying concept that motivates all human choices. Krueger et al. (2008) proposed a way of measuring society's well-being, based on time use and affective (emotional) experience by using the National Time Accounting (NTA) approach. NTA is a set of methods for measuring, categorizing, comparing, and analyzing the way people spend their time.

Focusing on individuals, it was found that the effect of income on SWB is clearly and unequivocally positive: high income earners have a higher degree of SWB than low-income earners within a given country and at a given point in time. This relationship is highly significant in practically all studies, but the slope of the happiness-income relationship might vary (see for example Boes and Winkelmann, 2006; Clark et al., 2005). In addition, the correlation is more pronounced for the lower half of the income distribution, and weaker for the upper half, suggesting a curvilinear relationship that is consistent with diminishing marginal utility of income (see Fig. 1).

Since decision makers seek to implement policies that improve the quality of life, these findings suggest that it is advised to focus on lower income groups. For the transportation sector, this means that decision makers should concentrate on promoting projects that address populations with lower well-being level who rely more on public infrastructure. Such investment may lead to a significant increase in their level of well-being, and therefore are more meaningful.

2.2.2. Project evaluation methods

A variety of methods have been suggested for the evaluation of transport projects, but the Cost Benefit Analysis (CBA) which became the accepted standard is the most widely used (Odgaard et al., 2005). CBA's core limitation regarding equity issues is that it does not differentiate among different beneficiaries of a project or policy. CBA considers only aggregated gains and optimizes the total welfare, but it does not enable to reflect on welfare gains or losses of specific groups or people. Therefore, it limited in its ability to account for equity considerations.

Additionally, CBA, which is partly based on the application of a travel demand model, can potentially lead to an optimism bias, stemming from the way these models are used and a distributive mechanism that structurally favors transport improvements for highly mobile groups (Mackie and Preston, 1998), as well as from cost underestimation (Flyvbjerg et al., 2003). This bias is associated with time savings, typically accounting for the vast majority of benefits generated by a transport investment, and with the way in which the monetary value of these savings is calculated. The theory underlying

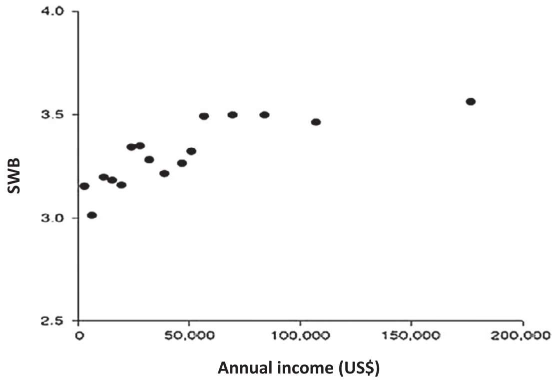

Fig. 1. Individual cross-section evidence - income and SWB in the US in 2008. *Source*: Hirata (2011).

CBA suggests using the monetized travel time benefits, which is determined through Willingness to Pay (WTP), and thus varies with income. The implications of using WTP values are that transport investments primarily benefit higher income groups (Martens, 2006).

The ''Equity value of travel time'' value was meant to correct the bias inherent to CBA, and is used in most countries that utilize CBA. This value is based on an average income level and applies for all travel time savings, independent of the income level of the traveler (Morisugi and Hayashi, 2000). Although it promotes equity to some extent, at the same time it eliminates considerations and preferences of each individual which are reflected in the WTP.

Similar to the ''Equity value of travel time'' concept, ''distributional weights'' can be applied to address equity concerns (Mishan, 1976; Johansson-Stenman, 2005; Stevenson and Wolfers, 2008) although this has rarely been applied to CBA (Campbell and Brown, 2003). Given an existing distribution of income, decision makers may attach a different value (weight) to the creation of a certain monetary gain for different groups (Martens, 2011; Schofield, 1987). It is from the concept of diminishing marginal utility that distribution weights are rationalized and derived. Given that marginal utility declines as income and consumption increase, the higher the level of income and consumption, the lower is the distributional weight. In this work, we derive the assigned weights from the well-established SWB-income relation (as discussed in Section 2.2.1) which hasn't been used before in transportation studies, and can overcome the bias resulted from using values of travel time.

Another problem with CBA lies in the correlation of the total number of trips and the total benefits generated by a transport improvement. Wealthier population groups enjoy higher rates of car ownership, and the number of trips they make is higher. As a consequence, their impact on evaluation outcomes is stronger, as more trips for a particular link can be translated into more travel time savings resulting from the investment in that link. This can result in bias towards transport investments that benefit wealthier groups.

Multi-Criteria Analysis (MCA) is an alternative appraisal technique to CBA, constructed to overcome CBA's limitations (Thomopoulos et al., 2009). MCA has been used in various disciplines to assess project impacts, especially in environmental and social studies. MCA requires that decision makers attach weights to a number of criteria to evaluate policy alternatives (Shiftan et al., 2002). It has the advantage of comparing virtually all types of possible impacts. However, the major weakness of this method arises from its major strength: value judgments of decision makers are required, and altering the weights can greatly influence the results. Additionally, as is in the CBA, there is a danger of double-counting while applying MCA, since the criteria for including different effects are unclear and inconsistent (Annema et al., 2007).

Thomopoulos and Grant-Muller (2013) proposed a new method that incorporates equity impacts into the appraisal framework, and is based upon a composite indicator and MCA. In addition, there have been some attempts to bring the CBA and the MCA together in a single evaluation framework – a good example is the Japanese Benefit Index Table (BIT), further discussed below (Bristow and Nellthorp, 2000; Morisugi, 2000). Along similar lines, our research suggests a framework incorporating both approaches into a new equity oriented approach, ''Equity Benefit Analysis'' (EBA), which is capable of maintaining the main advantages of each method (for a thorough discussion see Section 3).

2.2.3. Practical guidelines

In the last decade a range of countries have introduced new appraisal approaches, such as the New Approach to Appraisal (NATA) in the UK; Overview of Effects of Infrastructure (OEI) in the Netherlands; the Federal Transport Infrastructure Plan (FTIP) in Germany, and the Benefit Index Table (BIT) in Japan (Thomopoulos et al., 2009). All of the above approaches use CBA as their main foundation. Fewer countries have incorporated equity considerations into the evaluation process, mostly using MCA. Among the EU Countries, only Spain, UK, Switzerland, Czech Republic, and Hungary, have been applying a variant of MCA for equity evaluation. However, none of these countries except for the UK has done this in a systematic way and for every project.

In Japan, a variant of MCA is applied, although CBA has been adopted as a basis. In the Japanese manual the social equity viewpoint is only vaguely considered, using a Benefit Incidence Table (BIT). The BIT is a qualitatively list of indicators that should be monetarily evaluated and account for as part of the investment. The indicators are divided by sectors; and the equity balance between sectors is judged based on the net benefit distribution. Multiplying the distributional weight, which reflects the social value judgment, could modify the net benefit of each sector (Morisugi, 2000).

Yet, the CBA guidelines of most of the developed countries around the world partially address the equity consequences by using the so-called 'equity values of travel time' (Martens, 2007; Morisugi, 2000; Quinet, 2000 and Vickerman, 2007), mentioned above. The use of equity values is virtually the only way in which equity considerations are addressed in current CBA practice around the world, with the exception of Germany. The German procedure applies equity concerns by evaluating regional disparities. This is achieved by assessing the "Beneficial Spatial Effects"; this assessment is linked to the level of unemployment in a region and the benefits that could be gained from an 'improved spatial situation', for the 20 regions with the lowest GVA/capita. The "Beneficial Spatial Effects" measure is based on employment effects during the construction period, employment effects related to the operation of new infrastructure, benefits from reduction of vehicle operation costs, and benefits from time saving. However, the German procedure has been shown to produce double counting of benefit measures such as cost and time saving effects (Rothengatter, 2000).

At the EU level, the HEATCO guidelines are the most recent of a series of guidelines/manuals/handbooks for project appraisal promoted in the last two decades by the EC and/or other international financing institutions (IFIs). Table 1 provides an overview of these EU level guidelines with respect to equity consideration (HEATCO, 2006). HEATCO approaches the issue of intra-generational equity,[1] and recommends, at minimum, that a "winners and losers" table should be developed and presented alongside the results of the monetized CBA. Distributional matrices for alternative projects might be created as a more sophisticated approach. Generating a distributional matrix requires analyzing the costs and benefits of alternative projects by income percentiles of the population affected by the projects. Various categories may be used, such as those based on geographic location, and car ownership, as has also been recommended by the French manuals (Quinet, 2000). A good example for the adoption of this suggestion is provided by the UK transport appraisal guidelines.

In Israel, a new appraisal framework, known as "Transport Project Appraisal (TPA), 2012", details a procedure aimed at determining how the accessibility improvements generated by a transport project are distributed over lower-income and higher-income communities. This is done by using the 'Community Equity Indicator': the ratio of the 'Average Aerial Speed'[2] (AAS) improvement for the rich communities to the AAS improvements for the poor communities. An additional equity measure that has been incorporated in the new Israeli guidelines is the Household Equity Indicator: a number that indicates whether the gaps in travel times between car-owner and car-less household have been reduced or increased (Martens, 2007). These additions to the new Israeli TPA indicate a clear trend of incorporating equity indicators that reflect the distribution of accessibility improvements across different sectors.

While EU guidelines permeated the understanding that the project's impact on different population groups should at least be presented, the guidelines/manuals/handbooks of EU countries do not deal with optimism bias associated with travel demand models and CBA.

2.3. Travel demand modeling and evaluation

A change in one's consumer surplus resulting from some policy is the change in her utility converted to money terms. The change in utility can be easily obtained from the choice model appropriate for the situation. If the unobserved component of the utility is independently and identically distributed according to the Extreme Values type 1 distribution, and utility is linear in income, then the expected utility is the log of the denominator of a logit choice probability plus an arbitrary constant. This term, commonly referred to as logsum, can be monetized by dividing it by the marginal utility of income to obtain the consumer surplus.

2.3.1. The "Logsum" as an evaluation tool

The theory on using logsum changes as a measure for the change in consumer surplus was published in the late seventies and early eighties (De Jong et al., 2005); however, in practice the application of this theory has been quite limited. Some scholars have used logsum in destination choice and/or departure-time choice models (e.g., Gupta et al., 2004; Kalmanje and Kockelman, 2004). De Jong et al. (2005) reviewed the theoretical and applied literature on the use of logsum as a measure of consumer surplus change in project appraisal. They describe a case study in which the logsum method and the commonly used 'Value of Travel Time' method were compared for a specific project. Zhao et al. (2012) explore the use of logsum in the evaluation of welfare impacts for transport policies within finite population settings. Depending on population size and the error-term correlation structure, they find that logsum approximation may be considerably different from the numerical simulation. Castiglione et al. (2003) converted logsum changes to time in minutes, but more commonly one or more cost coefficients are used to convert logsum to money units. Geurs et al. (2010) examined accessibility benefits associated with possible land-use policies in the Netherlands, taking into account climate change. Kockelman and Lemp (2011) emphasized the revenue-generation opportunities and welfare impacts for various road pricing policies. Morey et al. (2003) incorporated substantive income effects in a logit or nested-logit model by approximating individual's compensation

[1] Consideration of intra-generational equity relates to how a project affects different social groups disproportionately in terms of income distribution.

[2] The AAS is defined as the quotient of, on the one hand, the aerial distance between a community and all other destinations in the study-area, and, on the other hand, the travel time on the transport network between a community and all other destinations in the study-area.

Table 1
DG regional policy guidelines, TINA, RAILPAG, HEATCO: a comparative overview. *Source*: HEATCO, 2006.

	DG Regional Policy 2003	TINA 1999	RAILPAG 2005	HEATCO (2006)
Equity (intra-generational)	Either included in CBA (through shadow prices) or in MCA (quantified e.g. through statistical measures such as Gini index). No disaggregation of impacts between stakeholder categories	Disaggregated results of CBA (per type of user, public vs. private, etc.)	Disaggregated results of CBA through Stakeholders-Effects Matix (SE Matix)	Winners and losers tables at minimum, distributional matrices as a more sophisticated approach

variation using the logsum. Golub et al. (2009) measured welfare changes, using logsum, in a discrete choice framework, in order to estimate proposed policies' impacts on different users in Rio de Janeiro.

2.3.2. The activity-based accessibility measure

Activity Based Models (ABM), the state of the art in travel demand models today can capture the entire picture of an individual's activities, and are able to account for trade-offs among various activities and travel alternatives in one's daily activity pattern. Thus, they provide better understanding of travel behavior, compared to traditional modeling and serve as a good basis to develop more appropriate accessibility measures. (see for example: Kitamura, 1988; Ben-Akiva and Bowman, 1998; Arentze and Timmermans, 2000 and Shiftan, 2008).

Other disaggregate models can give results by various groups of the population, yet they cannot generate the Activity-Based accessibility (ABA) measure which has a clear advantage for equity analysis (Bills et al., 2012), and therefore is used in our study. The Activity-Based accessibility measure (ABA) was first presented by Ben-Akiva and Bowman (1998), who defined accessibility as the expected value of an individual's maximum utility across possible activity schedules, given the choice alternative. Specifically, they use:

$$\frac{1}{\mu}\ln\left(\sum_{j=1}^{j}e^{\mu V_{nj}}\right) \tag{1}$$

where V_{nj} is the "representative"/modeled utility that traveler n obtains from alternative j (n = 1,. . .,N; j = 1,. . .,J), and μ is the scale parameter.

The ABA measure, obtained from the underlying DAS model system, can be used to study a person's access to various activities and how it affects his choice set. The "logsum", the log of the denominator of this logit choice probability, gives the expected utility from a choice (out of a set of alternatives), and can be used to link different choices (as in nested logit models). The logsum can also be used in project evaluation as it expresses the consumer benefits, as discussed above in Section 2.3.1. The sum of all logsums at the top level of the hierarchy is the "top" accessibility measure - the ABA measure capturing the overall utility from all the travel alternatives over the various dimensions: destination, mode, time, and travel patterns.

The ABA measure allows one person to have different accessibilities for different choice situations, depending on his/her characteristics. This measure accommodates individuals' probability to participate in a variety of activities, combination of activities through trip-chaining, entire day activity patterns, and the scheduling of activities. Its key aspects are that it captures the relative attractiveness of various alternatives for activity participation, trip combination, travel mode, and timing, reflecting not only the nature of land use and properties of the transportation system, but also the socioeconomic characteristics of individuals (Dong et al., 2006).

Along with its benefits, similar to the traditional approaches the ABA measure is also biased towards higher income groups, as it is dominant by the value of time (see Section 2.2.2). Even studies that suggested to expand the evaluation to include subjective values in the utility function, and by that to conduct a more accurate evaluation of consumer's benefits, still suffer from the same bias that relates to the value of time savings. This can overcome by using the new measure offered in this work.

3. Methodology

Here, we develop an innovative framework and a measure accounting for both efficiency and equity effects. We include social and spatial factors in social welfare assessment by introducing the concept of gains of accessibility to key social activities. In order to assess the full consumer's benefits from transportation project implementation, and calculate the improvement in accessibility, we suggest using us ABM and the ABA measure as it captures the overall utility from all travel alternatives over various dimensions. We further convert the ABA measure to SWB reflecting the magnitude of the income – well-being effect on different population groups, and compensates for differences in income by translating the accessibility benefits into well-being terms. As a consequence, the consumer's surplus is turned into consumers' subjective well-being. Considering both the change in accessibility calculated at the top of the hierarchy (i.e. ABA), and the income - well-being effect (SWB), we obtain an alternative measure in well-being (benefit) terms, "Subjective Value of Accessibility gains" (SVOA). SVOA disconnects the influence of number of trips on benefits, and compensating for income differences by including subjective well-being factors, thus guaranteeing more equitable distribution of resources. Thus, SVOA reflects greater benefits from policies that are geared more towards the less accessible and lower income population. This is the first study using a combination of the SWB and ABA to develop a new evaluation measure.

We use this new measure, the SVOA, as the key benefit taking into account in a new equity oriented approach – "Equity Benefit Analysis" (EBA). EBA is a hybrid of CBA and MCA. It effectively maintains the advantages of each method while avoiding the drawbacks discussed in Section 2.2.

3.1. Theoretical framwork

As explained above in Section 2.3, logsum can be used as an expression for the consumer benefits. The logsums received at the very top of the hierarchy are the ABA measure as provided by Dong et al. (2006). If ABA_n^0 denotes the accessibility value for traveler n before implementing any transportation policy, and ABA_n^1 denotes the same measure after implementing the transportation policy, then the accessibility gain from the policy in utility units is:

$$\Delta ABA_n = ABA_n^1 - ABA_n^0 \tag{2}$$

Once the alternative that provides the greatest utility for traveler n was calculated, and assuming for simplicity that utility is linear in income,[3] the consumer surplus (CS) can be written in money terms as:

$$CS_n = \frac{1}{\alpha_n} \cdot U_n = \frac{1}{\alpha_n} \cdot \max_j (U_{nj} \forall j) \tag{3}$$

where α_n is the marginal utility of income and U_n is the overall utility person n obtains from alternative j. While we assume here for simplicity a linear in income utility function, it is possible to generalize this for other more general forms of utility functions.

If the model is a logit model and the marginal utility is constant with respect to income than the expected consumer surplus becomes:

$$E(CS_n) = \frac{1}{\alpha_n} \cdot \frac{1}{\mu} \ln\left(\sum_{j=1}^{j} e^{\mu V_{nj}}\right) + f \tag{4}$$

where f is an unknown constant that represents the fact that the absolute value of utility is unknown.

The total changes in consumer surplus can be defined as:

$$\Delta CS_n = \frac{1}{\alpha_n} \cdot \left[\frac{1}{\mu} \ln\left(\sum_{j=1}^{j^1} e^{\mu V_{nj}^1}\right) - \frac{1}{\mu} \ln\left(\sum_{j=1}^{j^0} e^{\mu V_{nj}^0}\right)\right] = \frac{1}{\alpha_n} \cdot \Delta ABA_n \tag{5}$$

where superscript 0 and 1 denote *before* and *after* the change in policy, respectively.

α_n is the marginal utility of income and is equal to dU_{nj}/dY_n if alternative j is chosen, and Y_n is the income of person n.

For a population that chooses j with probability P_j, the average marginal utility of income, A, is:

$$A = \sum P_j \cdot (dU_{nj}/dY_n) \tag{6}$$

Now:

$$dU_{nj}/dY_n = -dU_{nj}/dC_n \tag{7}$$

where C_n is the price of travel by alternative j. If we have utility function:

$$V = f\{C, T, \ldots\} \tag{8}$$

where C is cost in dollars, T is travel time in minutes and some additional variables, as de Jong et al. (2005) showed, ABA can be monetize:

$$\Delta CS_n = \Delta ABA_n \Big/ \sum P_j c_j (\text{in dollars}) \tag{9}$$

We incorporate the income - well-being factor, to reflect the fact that lower income consumers are more sensitive to changes in their well-being level (Hirata, 2011). Thus, the consumer's surplus becomes the consumer's subjective wellbeing:

$$\Delta CSWB_n = \alpha_{SWB_n} \cdot \frac{1}{\alpha_n} \cdot \Delta ABA_n \tag{10}$$

where α_{SWBn} is the income - well-being factor and is equal to $dSWB_n/dY_n$, which is the slope of the happiness-income relationship and varies as a function of income level.

[3] de Jong et al. (2005) explains that "for policy changes, that change the consumer surplus by small amounts per person relative to their income, the formula can be used with a current average value for α even though in reality the marginal utility of income varies with income".

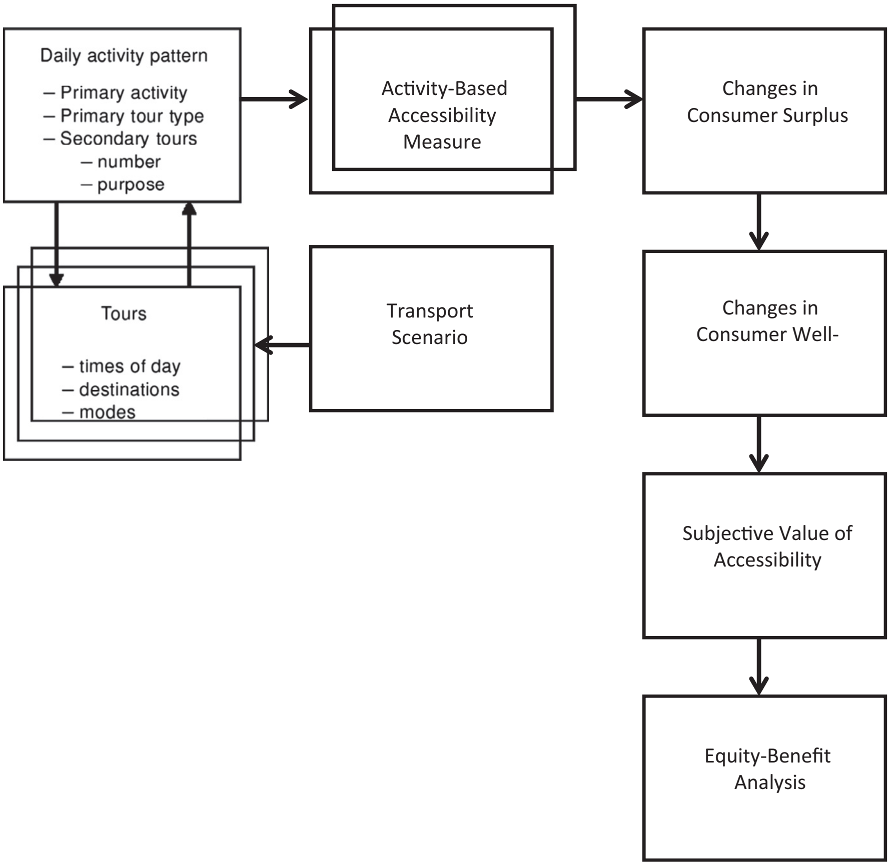

Fig. 2. Subjective value of accessibility calculation process.

Considering logsum changes calculated at the top of the hierarchy along with income - well- being effect, and we obtain a measure which we refer to as SVOA:

$$SVOA = \sum_{n=1}^{n} \left\{ (\alpha_{SWB_n}) \cdot \left(\Delta ABA_n \Big/ \sum_{j=1}^{j} p_j c_j \right) \right\} \tag{11}$$

The SVOA, expressed in well-being (benefit) terms, can then be used as the main measure in the overall EBA.

Fig. 2 illustrates the methodology specified above.

EBA allows the comparison of projects based on a single value, while putting more weight on lower income and accessibility-lacking groups, based upon the subjective relationship between income and well-being. SVOA, reflects consumer's benefits only, allows the inclusion of a variety of consumer's influences, and sums them systematically into a single measure. This measure is not intended to replace the current practice of analyzing equity by comparing various impacts on different groups of the population, but can provide policymakers with a single measure that promotes both equity and efficiency considerations in the comparison of alternatives.

EBA allows better assessment of peripheral projects. According to CBA, the economic benefits of peripheral projects may be questionable. However, with EBA these projects will rank higher as they serve to enhance the accessibility of lower accessibility consumers, who either live in the periphery or have less access to transportation. Rather than focusing on the absolute size of travel time-saving, the SVOA gains will consider, as Rawls (1971) suggested: "the greatest benefit of the least advantaged" members of society. This new measure can also capture, in a more systematic way, additional impacts besides time saving - as it is more sensitive to travelers' characteristics and opportunities.

4. Case study – activity participation and mode choice model

4.1. The model

The methodology was tested using a simple synthetic activity-based model accounting for activity participation and mode choice. For simplicity, we refrained from trying to assess the benefits from some transport project with a full ABM, and focused on a simple model with two choice dimensions: activity participation and travel mode. The benefits were estimated using ABA, expressed as the logsum obtained at the top of the choice model. The activity-based model is shown in Fig. 3. At the upper level of this model, the individual chooses whether to participate in an activity or not, and if she chooses to participate in an activity, she can choose between two modes to travel to this activity, auto or bus, at the lower level.

We assume the population is composed of two sectors, rich and poor, with different travel behavior characteristics, however, this can be easily generalized to more income groups to represent the distribution of income in the population. A simple synthetic model system was synthesized, where in the lower level there is a binary logit mode-choice model (Eqs. (12) and (13)), and in the higher level there is a binary logit activity-participation model (Eqs. (14) and (15)) including a logsum variable from the mode choice model as follow:

$$\text{For the ``poor''}: \begin{cases} V_{bus} = -0.02T_{bus} - 0.04C_{bus} + 0.5COM_{bus} + 1.7 & \text{(a)} \\ V_{car} = -0.02T_{car} - 0.04C_{car} + 0.2A & \text{(b)} \end{cases} \tag{12}$$

$$\text{For the ``rich''}: \begin{cases} V_{bus} = -0.04T_{bus} - 0.04C_{bus} + 0.5COM_{bus} & \text{(a)} \\ V_{car} = -0.04T_{car} - 0.04C_{car} + 0.2A & \text{(b)} \end{cases} \tag{13}$$

$$\text{For the ``poor''}: \begin{cases} V_{activity} = 0.008I + 0.7LS - 4.5 & \text{(a)} \\ V_{no\_activity} = 0 & \text{(b)} \end{cases} \tag{14}$$

$$\text{For the ``rich''}: \begin{cases} V_{activity} = 0.008I + 0.7LS - 3 & \text{(a)} \\ V_{no\_activity} = 0 & \text{(b)} \end{cases} \tag{15}$$

where C is cost in dollars, T is travel time in minutes, COM stands for comfort, defined as the probability to find a seat on the bus, A is the number of vehicles in the household, I is daily income in dollars, and LS is the logsum from the mode choice model.

To analyze differences in passengers' behavior, time coefficients were synthetically set to reflect common values from the literature (Cambridge Systematics, Inc., 2010; NCHRP, 2012), modified to reflect the two populations: high time coefficient (−0.04) for the "rich", and low time coefficient (−0.02) for the "poor". Cost coefficient was also chosen synthetically based on values recommended in the literature (−0.04), to ensure reasonable values of times. These time and cost coefficients were the same for both modes, i.e. for public and private transportation. In a random utility models, the ratio between parameters, the value of time savings in this case, is what mostly matter and not their individual values. Bus utility function for the "poor" (see Eq. (12b)) included a constant reflecting passengers' propensity to choose public transport in comparison to the rich. The number of vehicles in the household was synthetically set to reflect differences between the "rich" and the "poor", such that the "rich" have three vehicles in the household while the "poor" hold no vehicle as shown in Table 2.

The activity-participation utility function was defined identically for both sectors, and consisted of daily income and the logsum from the mode-choice model only (see Eqs. (14b) and (15b)). Daily income values have been synthetically set for the

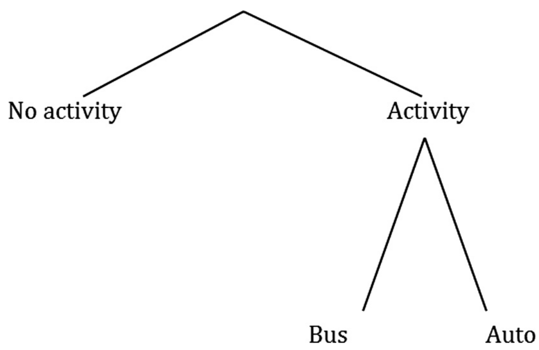

Fig. 3. Model structure.

Table 2
Variables' values in our case study.

Person	Car time (min)	Car cost ($)	Bus time (min)	Bus cost ($)	Daily income ($)	Number of vehicles	Comfort	SWB factor
"Rich"	40	5	65	5	700	3	0.6	0.15
"Poor"	40	5	65	5	350	0	0.6	0.5

two sectors: daily income of 700 $ for the "rich", and 350 $ for the "poor". The logsum, representing traveler accessibility, and the utilities were calculated for each individual, and used to calculate the probabilities of choosing to participate in activities and the mode to travel to these activities.

4.2. Scenarios

Two hypothetical scenarios were tested; the first one simulates public transport improvement, represented by a 25% reduction in travel time and a 15% increment in comfort (the probability to find a bus seat) for public transport users. The second scenario simulates road infrastructure improvement for private transport, by assuming a reduction of 25% in travel time for all private car users. We applied the synthetic model described above to estimate activity participation and mode choice changes resulting from these scenarios. We estimated the changes in passengers' benefits by calculating the differences in ABA for each passenger. These logsum differences were then divided by the cost coefficient, representing the marginal utility of income. Finally, we multiplied the change in consumer surplus by two separate SWB factors, corresponding to the two populations sectors, to reflect the fact that poor people are more sensitive to changes in their well-being levels than rich people. Hirata's (2011) findings were adopted for the calculation of SWB factors: 0.15 for the "rich", and 0.5 for the "poor" (see also Section 2.2). Thus, we estimate the change in consumer well-being for each person. The aggregation of this measure yields the SVOA, which reflect the total change in consumers' well-being, where the main benefit is the change in accessibility. For comparison purposes, we also calculated the change in consumer surplus in a traditional method using the 'rule of half' (monetized travel time benefits) as described in Section 2.2, and including benefits gained by the improvement in comfort.

4.3. Results and discussion

Table 3 presents dis-aggregated, cross-sectional changes in consumer benefit from the two scenarios, alongside the aggregates score, for both measures, the SVOA, presented in SWB or utility terms, and the monetized travel time benefits, presented in monetary terms. The analysis was performed using different time coefficients for the rich, and for the poor, as well as using "equity value of travel time". Given the different units of the SVOA and monetized travel time benefits, these measures cannot be directly compared, and can only be used to compare between the rich and the poor and between the scenarios within each measure.

The basic level of accessibility, before any improvements, that was obtained for the two populations, which is the logsum received at the top of the model, was 0.88 for the "rich" and 0.27 for the "poor".

For the first scenario, which included a reduction of 25% in travel time by bus and 15% increment in the probability to find a seat, the change in consumer's benefits using the SVOA is three times larger for the poor than for the rich. On the other hand, for the monetized travel time benefits the trend is the opposite - the change in consumer's benefit is 1.4 times larger for the rich than for the poor. Similar results are obtained while using "equity value of travel time".

Examining the results for the second scenario, of improving private transport infrastructure, the benefits measured by the 'rule of a half' (monetized travel time benefits) are more than 33 times larger for the rich than for the poor, and 18 times larger when using "equity value of travel time". The change in consumer's benefit for this scenario according to the SVOA measure is only 5.4 times larger for the rich than for the poor. Moreover, for the aggregated results of SVOA, the public transport improvement provides 2.5 times more benefits than the private transportation infrastructure investment, showing in this case a clear preference for the investment in public transport. In contrast, according to the monetized travel time benefits the private transportation infrastructure investment provides 1.05 times the benefits of the public transport improvement scenario, indicating, in this case, a preference for investments in private transport. The use of "equity value of travel time" changes this trend and leads to 1.2 times more benefits for the public transport improvement compared to the private transportation infrastructure investment. Overall, the use of "equity value of travel time" contributes to a more equitable evaluation of the projects, yet gives an inferior solution compared to the SVOA.

Table 3
Change in consumer benefit using SVOA and monetized travel time benefits as a main measure: summary results.

Scenario	Total change in benefits					
	SVOA (SWB)		Monetized travel time benefits ($)		"Equity value of travel time" ($)	
	"Poor"	"Rich"	"Poor"	"Rich"	"Poor"	"Rich"
Scenario 1: −25% in bus time and +15% in comfort	4.47	1.49	2.85	3.99	2.86	3.94
Total scenario 1	**5.96**		**6.84**		**6.80**	
Scenario 2: −25% in car time	0.37	2.00	0.21	6.97	0.28	5.03
Total scenario 2	**2.37**		**7.18**		**5.31**	

5. Conclusions

Transport project appraisal is commonly conducted using Cost Benefit Analysis (CBA). However, CBA is limited in its ability to account for equity issues. Furthermore, it has a built-in distributive mechanism that is biased, and it thus structurally favors transport improvements for highly mobile groups.

This paper explores transportation benefits from the consumer's perspective, not accounting for externalities such as noise, air quality, and safety. The approach presented in this paper challenges the prevailing approach for evaluating transportation projects, explains its weaknesses in relation to equity and offers an alternative. The new approach promotes better accounting for equity impacts in transport project appraisal by suggesting a framework and a single measure that advances both equity and efficiency considerations. This new equity oriented approach, EBA, alongside with CBA and a comparison of impacts for various groups, can provide rich information regarding the investment effectiveness both in terms of the impact on individuals and as an aggregate measure.

Our method builds upon activity-based models (ABM), which have two main advantages for equity analysis; First, they can account for all the individual benefits resulting from various dimensions of activities, including time and space. Second, they enable easy comparison of the benefits for different groups in the population. Along with its benefits, ABM are biased towards higher income groups, as it is dominant by the value of time (see Section 2.2.2). This can overcome by using the new measure offered in this work. While our example in this paper doesn't does not utilize all the benefits of ABM, it provides a simple and clear demonstration of a new alternative approach. It utilizes accessibility and subjective well-being factors, rather than value of time, to measure gains from transport investments, thus capturing additional impacts besides time-saving. Based on these building blocks the paper develops the Subjective Value of Accessibility (SVOA) measure, a utility-activity based accessibility measure combined with a well-being factor. Further research is needed to fully utilize and incorporate the full advantages of ABM into this approach.

To the best of our knowledge Subjective Well-Being (SWB) factors has not been used in transportation before. Furthermore, this is the first measure combining these two concepts of ABA and SWB into one evaluation measure so it can overcome the bias which relates to the use of travel time values. We demonstrate how SVOA can be incorporated into a new equity oriented approach, Equity Benefit Analysis (EBA), to advance both equity and efficiency. Unlike traditional measures that are biased towards higher income groups, this measure better caters for the needs of more vulnerable social groups.

Using a simple case study, we demonstrate the use of this new measure and compare it to the 'rule of a half', i.e. the monetized travel time benefits and the commonly used "equity value of travel time". The results show that these approaches can give rise to different estimates of population benefits in the evaluation, and can lead to different planning decisions. In our case study, for the public transport investments, SVOA showed more benefits for the poor than for the rich, while the monetized travel time benefits, and the "equity value of travel time" measure showed an opposite result. Moreover, when considering the aggregated results, SVOA measure provides more benefits for the public transport improvement than for the private transportation infrastructure investment, as also obtained using the "equity value of travel time", yet the SVOA measure provides clearer preference to the public transport investment. The monetized travel time benefits, on the other hand, provides more benefits to the private transport improvement scenario indicating a preference for this investment.

The opposite trends of SVOA and the monetized travel time benefits exemplified in this study can be explained by the fact that the population sector who chooses to travel by car is mainly the wealthier population (the "rich"), characterized by a higher value of time – a factor which influences the monetized travel time benefits. SVOA, on the other hand, is tailored to give higher scores for policies that are geared more towards weaker populations, which are more dependent on public transport. The inclusion of a well-being factor into SVOA facilitates this inclination.

The approach presented in this paper promotes the understanding of the accessibility barriers between different people and the socio-economic implications of these barriers. Such understanding has important practical implications, and can help embed equity objectives into transport policy and decision-making processes, and contribute to transportation investments that are more equitable. This approach is not free of limitations, which should be considered in further development and applications. First, the conversion to well-being is a key factor that affects the relative weight for the equity consideration. In our specific example it is based on the weights obtained in previous empirical studies, and thus depends on the specific sample and data collection method. Much more research is needed to validate the connection between income and well-being and potentially developing a method to well developing them for specific locations. Second, the conversion of benefits into monetary terms is based on the assumption that the marginal utility is linear with income. Obviously, this is not the case in reality. A practical way to overcome this problem can be by estimating the ABM by income group obtaining different marginal value of income for different income groups thus reducing the impact of this problem.

Finally, the ABM is usually based on the logit models for its various choice elements. This model has two mathematical advantages, first being relatively simple, but more important its characteristic that it has a simple term, the logsum, that represents the maximum expected utility from the choice situation. This second characteristic is what enables the calculation of expected benefit changes as a result of policy interventions. However, the standard or multinomial logit model also suffers from the Independent for assumption of Independence of Irrelevant Alternatives (IIA) which can cause some irrational behavioral changes, and thus can provide bias in estimates of travelers' behavior. The Nested Logit model provides a reasonable solution to this problem, that while somewhat complicate the model still provide the ability to calculate the expected maximum utility. However, in practice, constructing a full ABM with a full nested logit structure is still computational complex and various shortcuts are common, which their bias is unknown. More sophisticated models such as mixed logit and latent class models can better account for potential bias in travelers' behavior but would introduce a high level of complexity risking the practicality of the approach.

Despite these various limitations, we believe this approach can provide a practical good tool to policy makers. More research is needed to make this measure operational and to fully test its effectiveness. This requires research to overcome the limitations mentioned above and mostly the conversion of utility to well-being. Expansion of this simple synthetic model and population should include a full activity-based model, real data, real models, and a wider range of policies and investments scenarios, including an integrative activity based - land use model. Integration with more advance choice models including mixed logit and latent class models is also desirable. Such research will allow to conclude whether replacing the traditional procedure of using CBA with the newly suggested Equity Benefit Analysis indeed contributes to the integration of equity considerations in transport policy making.

Finally, equity impact of externalities such as air quality and safety should also be studied.

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