# SDA AND EXTENDED CBA – A NEW HOLISTIC APPROACH TO INCLUDE SOCIAL IMPACTS IN APPRAISAL PROCEDURES FOR ROAD INFRASTRUCTURE INVESTMENTS

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## ABSTRACT

Traditional evaluation methods have considerable disadvantages. The result of a conventional CBA is based on the total costs and benefits of the investigated alternatives. The distribution of the costs and benefits among different social groups and other social impacts are neither calculated nor taken into account. Existing disparities are not considered and can be increased by a decision based on such an evaluation tool. In Austria, a new set of tools for the assessment of road infrastructure projects was developed which endeavours to overcome the above mentioned problems. This set comprises the **e**CBA (**e**xtended **C**ost **B**enefit **A**nalysis) which includes the evaluation of the distribution of costs and benefits among different social groups, indirect third party effects (regional welfare caused by the investment) as well as the impact of induced/suppressed transport demand. The SDA (**S**ustainable **D**evelopment **A**nalysis) includes the three dimensions of the holistic term sustainability, social, ecological and economic impacts. The SDA makes the term sustainability operable to assess the impact of alternatives. The result of the analysis leads to an indicator for sustainable development which assesses the contribution of each alternative to sustainability on a scale from 0 to 100.

## 1. PROBLEM DEFINITION

Traditional evaluation methods have considerable disadvantages which can be described in the following way: The results of a conventional CBA are based on the total costs and benefits of the investigated alternatives within the study area. The distribution of the costs and benefits among different social groups and other social impacts are neither calculated nor taken into account for any political decision. Existing disparities are not taken into account by any decision based on such an assessment tool. Conventional CBAs do not take into account indirect third party effects, caused by regional and local economic developments as well as re-urbanisation which are due to a new infrastructure or new employment. Another weakness of conventional evaluation tools is the fact that they do not properly reflect all relevant environmental and social impacts. Even if the formal political decision does not require some of these results it is important for the preparation of the political decision to disclose all relevant information, welcome or unwelcome, to the decision maker and the public.

In Austria, a new set of tools for the assessment of strategic impacts of road infrastructure projects was developed which endeavours to overcome the above mentioned problems. This set comprises the **e**CBA (**e**xtended **C**ost **B**enefit **A**nalysis) which includes the assessment of the distribution of costs and benefits among different social groups, indirect third party effects (regional welfare caused by the investment) as well as the impact of induced and suppressed transport demand. The SDA (**S**ustainable **D**evelopment **A**nalysis) includes the three dimensions of the holistic term sustainability, social, ecological and economic impacts. The result based on transport demand figures obtained in transport modelling has a dominating influence on the assessment result. Therefore quality management standards for the input data from transport modelling are a key feature of assessment tools. Quality measures include the estimation of confidence intervals for the dimensioning traffic volume as well as the calculation of impacts depending on travel demand [1, 2]. On the higher level of planning decisions the investigated alternatives must comprise intermodal alternatives of infrastructure and organisational measures for all relevant modes in order to ensure a cost-efficient solution. The following text focuses on the SDA and the **e**CBA.

## 2. SUSTAINABLE DEVELOPMENT ANALYSIS

### 2.1. Definition of the term Sustainable Development

Nowadays the term *Sustainable Development* is used in an inflationary way by many professions, by experts such as spatial planners, economists, agricultural and social experts, financial planners or politicians and decision makers in local authorities and companies. If one analyses the decisions and actions of such people regarding the aspect of sustainability, only few seem to be aware of the true meaning of the term. But it is altogether positive that the term sustainable development has found entrance into the science and practical application of transport planning - at least into the vocabulary thereof [3]. In the history of mankind one can find many examples for *non-sustainable development* due to anthropogenic interference. One example from antiquity are the Romans whose intense logging of the densely forested Lebanon for their own ship-building purposes changed the region into a permanently deforested area. Centuries later the Venetians followed the Roman example: their radical logging changed the Croatian coast into a permanent karst region. The term *sustainable development* is first documented [4] in a publication about forestry. Simply put, the term means that one should not log more trees in a forest than can grow again within the same period of time. This is the only way for closed loop recycling management of a forest for generations. If one also takes the natural consumption of wood due to the dying back of trees and the anthropogenic production of wood, e.g. by planting new trees, into account, then, from an engineering point of view, the term sustainable development of wood as a resource can be operationalised by using the equation shown in figure 1 [5]. As one can see the term *sustainable development* is a *discrete* characteristic: sustainability is either present or absent, i.e. it is a "yes" or "no" characteristic. Anything in-between, for example *partly sustainable* is not possible. One has to take into account that a *sustainable development* requires a clearly defined and limited reference period [6] because our globe and our solar system will not exist for ever. To achieve real sustainability the period under review must include several future generations. Usually periods considered for cost-benefit analyses are based on the life time of infrastructure buildings for a railway section or a road and are thus too short. To monitor sustainability the selected reference period needs to be divided into time intervals which correspond to the phases of management activity.

| | | | | | | |
|---|---|---|---|---|---|---|
| **A**nthropogenic **c**onsumption of timber by transport | ≤ | **N**atural **g**rowth of timber | - | **N**atural **u**se of timber | + | **G**rowth of **a**nthropogeni-cally generated timber |

$$AC \leq \int_{t_0}^{t_1} NG(t) \cdot dt - \int_{t_0}^{t_1} NU(t) \cdot dt + GA$$

t = time

Figure 1 – Operationalisation of the concept *Sustainable development* from an engineering point of view, using the resource forest as an example [5]

The term *sustainable development* in its current meaning is mainly based on the Brundtland Report [7] and the declaration of the "*United Nations Conference on Environment and Development*" in Rio de Janeiro 1992: *Sustainable development* means that the present generation can meet its own needs without damaging those of future generations. It is based on a balanced development of the three dimensions ecology, economy and society. In this context *Sustainable development* is an optimisation concept which should become the leading maxim for human behaviour.

## 2.2. Operationalisation of the concept of sustainable development in transport

The term *Sustainable development* as defined above provides only a qualitative and rather general description open for interpretation. Operationalisation means that the term needs to be adapted in such a way that it can be used in daily work to help us optimise, assess and check our actions to achieve a sustainable development. We need a holistic assessment process to assess all effects of investments in the transport infrastructure. This includes the so-called input effects, e.g. the consumption of resources (consumption of land, raw materials, energy and fuel, travel time consumption, cost) due to extensions of the road network but also output effects, e.g. the social and environmental impact (exhaust emissions, the impact of noise on health etc.). This leads to a number of questions which beg answers and solutions to make it possible to operationalise the concept of sustainable development for an extension of the transport network. This article can only deal with some examples of such questions. There are no satisfactory solutions for all issues and such solutions are only briefly covered in this article.

### 2.2.1 *Separated impact of individual measures – overlapping impact*

The separated impact of individual measures can be fairly accurately determined. It becomes more complex if for example various components of exhaust fumes overlap because the impact of the accumulated pollutants upon health is not a linear additive aggregation. The situation is even more complex if the impacts of various aspects overlap, e.g. if the same group of the population is suffering from the negative impact of traffic noise on health and is also faced with an increase in its cost of mobility. Low-income target groups are more affected than high-income ones because in general the initial health situation of low-income groups is more critical.

### 2.2.2 *Acceptance of compensation effects*

The issue of compensation effects is particular important for the assessment of the impact of measures on a sustainable development: Is it possible to compensate for a lack of ecological impact by a bigger positive economic impact? To give an example: Should it be permitted to compensate a group of people in a financial way for noise above the permitted limit? The methods currently used for a cost-benefit analysis as a basis for decisions about infrastructure measures permit such compensation effects for all impacts. To give an example, this means that high accident costs can be set off against a reduction of the operating and maintenance cost of the traffic infrastructure. A possible solution for this problem might be the definition of standardized limits (e.g. a noise limit) for the impact in question which have to be met in all cases. This would mean that compensation effects are only permitted as long as the clearly defined limits are not exceeded.

### 2.2.3 *Time frames*

In addition to the need to select a suitable period for review of the sustainable development as mentioned above, attention needs to be paid to the selection of suitable periods for repeated observations or "measuring" of the status of the sustainable development. Because of the cost and time involved permanent observations are not possible. Therefore suitable points in time need to be defined for the observations. From the point of view of sustainable development these points in time must be sufficiently representative for the timespans in-between. This is particularly important if certain impacts show some seasonality, e.g. the concentration of particulate matter in conurbations is particularly high in winter.

### 2.2.4 *Differentiation and size of spatial and target-group related aggregation units*

For the evaluation of a sustainable development the spatial aggregation units (districts, municipalities, regions, countries, etc.) have to be selected for any area of investigation in such a way that unwanted compensation effects cannot occur. As far as their sustainability status is concerned, the spatial aggregation units selected have to be functionally effective units. It should be prevented that in the overall assessment sections of a spatial aggregation unit with no sustainable development can be completely ignored or compensated for by sections with nearly ideal sustainable development. Such neglect of a target group would occur if a minority of inhabitants of a municipality with poor access to the road infrastructure would be compensated for by the majority with excellent access. This can happen with indicators based on the average of both groups of people.

### 2.2.5 *Analysis process*

For an operationalisation an analysis process based on clearly defined standards is necessary for the assessment whether or not a development is sustainable. Such processes can be used for vastly different applications. Urgently needed is a process for the assessment of the sustainable development of an existing or future situation (trend) of transport systems or the impact of organisation or infrastructure-related traffic measures. A whole range of established assessment processes are available for economic assessments, such as the cost-benefit analysis, the cost-effectiveness analysis etc. Some first steps to find procedures for a holistic evaluation of sustainable developments look promising [8] but so far a sufficient standardization and professional recognition is missing. For example, the use of a complete quantification and value synthesis of sustainability criteria is documented in two studies, one about the assessment of measures for the conurbation Vienna up to 2035 [9] and one about the assessment of the development of an express road [10]. The current state, the trend, and the various scenarios of measures were assessed with the help of an "index of sustainable transport development" (figure 2). This method is based on the multi-criteria analysis and is called "sustainable development analysis (SDA)".

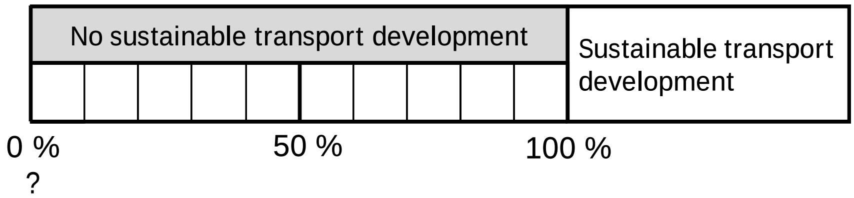



Figure 2 - Assessment index of *sustainable transport development (Sustainability index)*

### 2.2.6 *Assessment index of sustainable transport development*

The assessment index of *sustainable development* shown in figure 2 is called the sustainability index. It attempts to aggregate the complex term sustainable development in a kind of value synthesis in one variable. Obviously, the various dimensions of the term sustainable development are lost in this process. In order to decide whether a certain development points in the right direction towards "more sustainability" or whether some measure contributes in a positive or negative way to a sustainable development, it is necessary to have the detailed information which has been aggregated. Although there is some risk that such an assessment index might make the whole issue look trivial one has to bear in mind that any decision for or against an extension of the transport network will always be a yes or no decision. That is a "discrete" decision which can be expressed as a binary variable. In order to reach such a discrete decision one needs an assessment in the same form which contains all the relevant information. The assessment index for sustainable development is expressed with the help of a scale; any development on the right of the value 100% is *sustainable* and any development on the left of this mark is *not sustainable*. This scale allows for a qualification and assessment how far away a non-sustainable situation is from the target sustainability. The lowest value on the scale, 0%, can be considered as "worst case scenario" in regard to sustainability. One can also interpret the area to the right of 100%: any value marginally higher than 100 % means that the situation, although just sustainable, offers little security and stability, quite different from a value considerably higher than 100%. This assessment index of sustainable development permits the monitoring of the current development as well as the assessment whether any traffic measures contribute to a sustainable development, in a comprehensible, standardised, and quantifiable way.

### 2.2.7 *Steps in the sustainable development analysis*

Up to a certain degree the sustainable development analysis is a standardised process, which permits the assessment of the contribution of transport infrastructure measures to a sustainable development in the same way as a cost-benefit analysis is used for the financial evaluation from an economic point of view. The process follows the multi-criteria analysis. But certain unusual features need to be taken into account. The following steps are part of the process:

*(1.) Definition of the superior and subordinate objectives with the help of a hierarchical objectives system:* The three equally important superior objectives are

warranting the economically, ecologically and socially sound transport development for present and future generations. Every superior objective is subdivided into subordinate objectives which describe the three superior objectives as well as possible in a representative way for all transport-related areas of action which are relevant for the sustainability. Figure 3 shows some examples of such areas for which objectives related to a sustainable development of transport need to be defined.

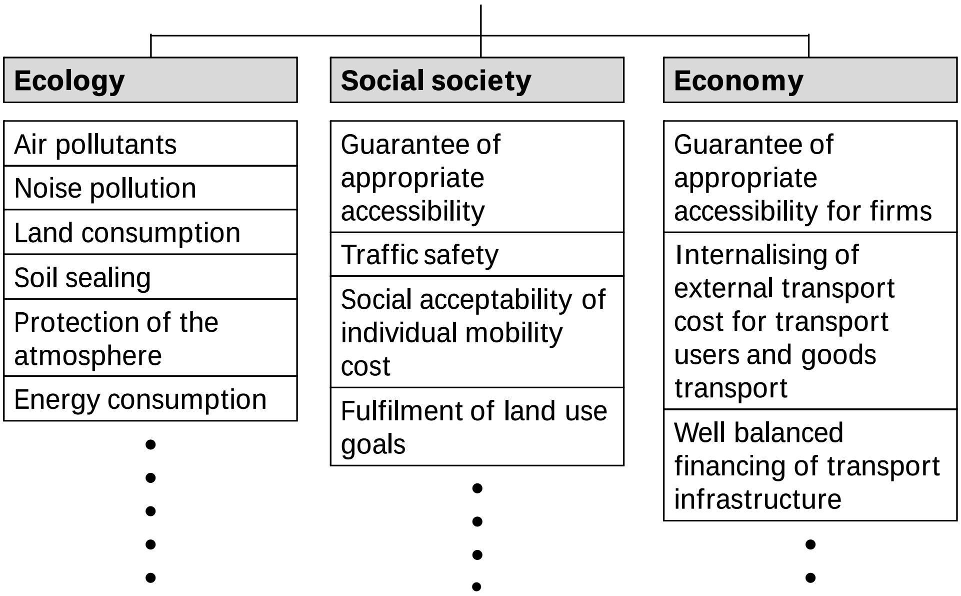
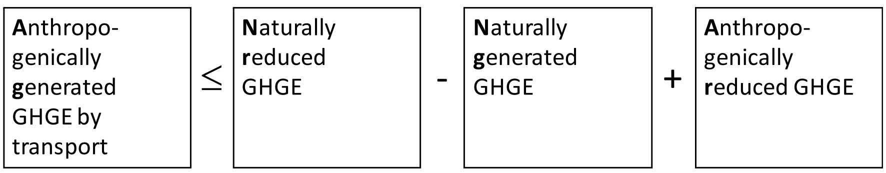



Figure 3 – Examples of areas of action related to the different objectives of a sustainable transport development

*(2.) Definition of the criteria of a sustainable transport development:* To operationalise the term sustainable development, for every subordinate objective a criterion for the fulfilment of the sustainable development, i.e. 100% on the sustainability scale, has to be defined, as well as a criterion for the value 0%. For every subordinate objective the first criterion defines the limit from where on the area of action can be considered sustainable. The second criterion defines the worst possible case. Figure 4 shows the operationalisation and the definition of the criteria for greenhouse gas emissions.




$$AG \leq \int_{t_0}^{t_1} NR(t) \cdot dt - \int_{t_0}^{t_1} NG(t) \cdot dt + AR$$

t = time

Figure 4 - Operationalisation and definition of the criteria for a sustainable development of traffic for the area of action "greenhouse gas emission GHGE"

*(3.) Definition and quantification of indicators and limits:* For every subordinate objective or criterion one or more indicators have to be defined which is/are most suitable to describe the objective quantitatively. For these indicators and all project

alternatives or variants the respective quantitative values have to be established or estimated. The limit values are the criteria defined in the previous step.

*(4.) Definition of the transformation function and calculation of the partial indices for all subordinate objectives:* A suitable transformation curve has to be defined for every indicator to transform the value of the indicator into a corresponding value of the partial index for sustainable development of the corresponding subordinate objective. In this process, the previously defined limit values for 0 and 100% on the sustainability scale have to be respected. The result is a partial index value for every indicator or every subordinate objective which indicates the sustainable development in regard to the subordinate objective considered. In the example shown in figure 5 the partial index for a sustainable development regarding the criterion considered in the example is 100%, if the external costs of transport users (car and public transport users) are fully covered and it is 0% in the case of no coverage at all.

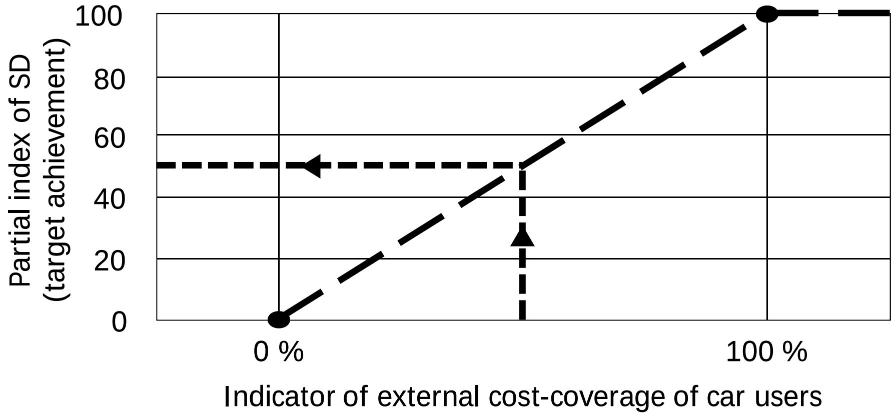



Figure 5 – Value-function for the criteria of external transport costs of transport users

*(5.) Value synthesis of the partial indices:* In a two-stage weighting process the partial indices are aggregated to obtain the assessment index for sustainable development. In a first step the partial indices for the subordinate objectives are aggregated separately for each one of the superior objectives ecological, economic and social development. Weights for the subordinate objectives have to be selected in such a way that they represent the relative impact of each individual subordinate objective upon the superior objective compared to the other subordinate objectives. It is beyond the scope of this article to provide details, but in the weighting process it is possible to take synergy effects of indicators or their impact into account [8]. If synergy effects are taken into account, a suitable and comprehensible process has to be developed and documented. If appropriate it is also possible to use "dynamic" weighting in regard to the value of the partial index considered, if one expects different synergy effects for the values 0 and 100% on the sustainability scale for individual impacts of subordinate objectives or indicators [8]. In the second stage of the weighting process the partial indices of the three superior objectives, ecological, economic and social transport development are aggregated into the assessment index for sustainable development. Each of the partial indices has the same weight of 1/3.

*(6)Assessment index for sustainable development:* The result is an index which describes all scenarios investigated in regard to the sustainable development (figure 2).

## 2.3. Case study Vienna Region

The operability of the SDA can be demonstrated with the help of this case study [9]. The result indicates that this technique is ready for application but it is clear that further development and research are desirable. The case study comprises the assessment of bundles of measures for three scenarios: The existing situation of the transport system and two alternative bundles of measure:

- Scenario Trend A (business as usual)
  - Infrastructure development in accordance with the transport master plan of Vienna
  - Extension of parking restrictions
  - Decentralized development of housing.

- Scenario A with additional measures to achieve the objective sustainability
  - Road pricing in the city centre of Vienna for cars 0.04 Euro/km, in the surrounding area 0.02 Euro/km, and doubling of the price during peak hours
  - Reduced extension of the road network compared to the transport master plan of Vienna
  - Strong promotion of public transport and non-motorized mode
  - Mobility management obligatory for enterprises
  - Promotion of alternative engine technologies
  - Campaigns to influence public awareness.

The result had a sobering effect on the decision makers and transport experts (figure 6). The existing situation reaches a level of 55% on the sustainability-index. The trend scenario A indicates a decrease in the index value for the year 2035. The scenario with restrictive measures affecting car traffic achieves 64%, well below the defined goals of the master plan of Vienna to achieve a totally sustainable development.

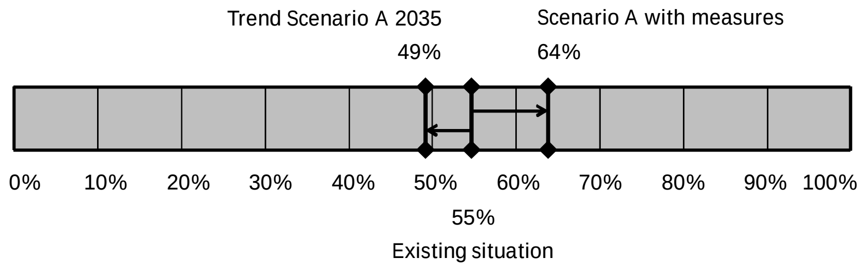



Figure 6 - Result of the SDA for three scenarios of bundles of transport measure for the Vienna Region (Austria)

Figure 7 shows the contribution of the various key criteria to a sustainable transport development in this case study about the Vienna region. It is obvious that a number of the bundles of measures in the trend scenario lead to a less sustainable development, for example an increase in greenhouse gas emissions, an increase in travel time due to traffic jams and a worsening of commuter accessibility in consequence of the traffic jams. Measures in the areas of action air pollution and cost coverage lead to a better sustainable development, even in the trend scenario. This is mainly due to the reduced-emission vehicle technology. In scenario A with additional measures all areas of action shown here contribute to a sustainable transport development, but there are considerable differences in the individual contributions. The comparatively low reduction in greenhouse gas emissions contributes least; the biggest contribution comes from the increasing cost-coverage due to an area-wide road toll in scenario A with measures.

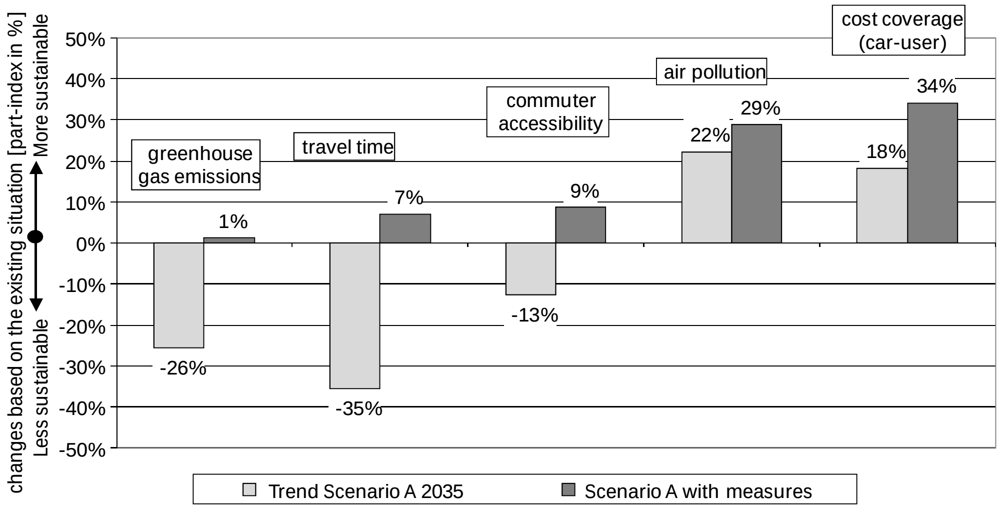



Figure 7 – Contribution of key criteria to a sustainable transport development in the Vienna Region [9]

## 3. EXTENDED COST BENEFIT ANALYSIS

The result of a conventional CBA is based on the total costs and benefits of the investigated alternatives. The traditional CBA includes mainly direct effects which can lead to an underestimation of the total benefit. The distribution of the costs and benefits among different social groups and other social impacts are neither calculated nor taken into account. Existing disparities are not considered and can be increased by a decision based on such an evaluation tool. The overview in figure 8 shows which impacts are covered by the traditional CBA and which are not.

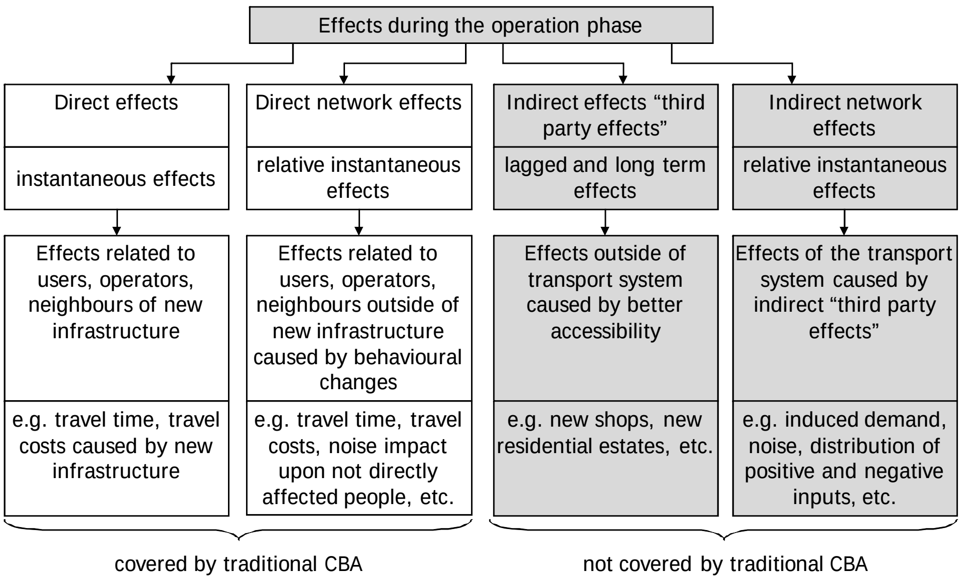



Figure 8 – Overview of effects and impacts caused by transport infrastructure investments [11]

The development of the extended Cost benefit Analysis (eCBA) closes some gaps and is a promising extension of the conventional CBA with three elements:

(1.) The regional economic added value is estimated dependent on the change of accessibility caused by the investigated measures. The accessibility is measured in a standardised way and based on the change of travel time or generalized costs.

(2.) The economic effect of induced/suppressed travel demand caused by an increase or decrease of the generalized user cost is assessed; the consumer surplus of the induced travel demand can be up to 10 % of the total benefit.

(3.) The distribution of costs and benefit is disclosed: who wins or loses what, when, where, and how much?

### 3.1. Added value in a region

The value added in a region is due to factors outside the transport sector. The improvement of accessibility in consequence of an investment in the transport infrastructure also improves the quality of any adjacent area. This advantage of the location induces companies and stores to move there, determined to benefit from the advantageous location. The increased demand for real estate and factory space lets prices for real estate and rents rise. This is a significant contribution to the added value the region generates. Studies show that the value-adding process only happens under certain conditions, e.g. if there is sufficient property for sale or rent, a certain investment potential and willingness to invest as well as a positive economic development [11]. One has to bear in mind that not every new company in an area with improved accessibility means an overall higher added value. It might happen that some companies move from an area with poor accessibility to one with better accessibility. Investments in the infrastructure lead to competition among locations and that might cause a lower added value in some of the less competitive locations. It is difficult to quantify the added value sufficiently well, but some studies [12, 13] have proved that it is generally possible. Simply put, it is necessary to define a suitable indicator for the change in accessibility due to the changed impact of the extended transport network as well as a suitable functional correlation between the added value of a region, the real estate prices and rents on the one hand and the change in accessibility on the other hand; a calibration on the basis of observed data is required. (Table 1)

Table 1 – General functional relationship between accessibility, generalized travel cost, added value in the region and variables of the spatial patterns

| | |
|---|---|
| $AC_i = \sum_{i,j}^{n} SV_j \cdot e^{\beta \cdot UC_{i,j}}$<br>$UC_j$: Generalized user cost from zone i to j<br>$SV_j$: Variable of regional structure of zone j (eg. residents, employees) | **$AC_i$: Accessibility of zone i**<br>i,j: Index of zones<br>$\beta$: Coefficient of regression |
| $REVA_i = CSV_i^{\alpha} \cdot DAC_i + k$<br>$CSV_i$: Combination of variables of regional structure of zone i<br>$\alpha$,k: Coefficients of regression<br>*Statistical explanation quality: 0,26=$R^2$=0,29 [13]; 0,52=$R^2$=0,98 [12]* | **$REVA_i$: Regional economic value added**<br>$DAC_i$: Difference of accessibility after and before investment in zone i |
| $LVA_i = LUA_i \cdot DLP_i + k$<br>$LP_i = AC_i^{\alpha} \cdot$<br>$\alpha$,k: Coefficients of regression<br>*Statistical explanation quality: 0,39=$R^2$=0,41 [13]* | **$LVA_i$: Land value added of zone i**<br>**$LP_i$: Land price per area unit in zone i**<br>$LUA_i$: Land use area of zone i<br>$DLP_i$: Difference of land use price after and before investment in zone i |

Table 2 shows three examples of projects for successful estimates of the value added in a region due to improved accessibility caused by investments in transport infrastructure projects in Austria. The motorway project is planned while the railway project is partly under construction and partly already being built. The extension of the underground lines has been achieved, so we have an ex-post study. The added value achieved in the respective region in one year is shown in the table as a percentage share of total investment cost. It is obvious that the estimated sums per year account for a comparatively large share of the investment. It is quite striking that the motorway achieves a nearly six times higher share of the respective investment than the railway project. On the one hand this can partly be explained by the more area-wide effectiveness of the investment in the road project, because the road network is far denser than the railway network. On the other hand, travel demand affected by the improved accessibility due to the improvement of the road network is considerably bigger than the demand affected by an improvement in the railway system. But one has to bear in mind that the added value presented here does not take the impact on the environment and accidents into account. Moreover, one cannot add these results to the results of a traditional cost-benefit-analysis because there might be some double counting, particularly as far as the reduced travel time is concerned.

The value added by the underground project contributes least to the investment cost. This is due to the very high investment cost per kilometre of the network and the nearly fully used development potential because the area along the two underground lines was already densely populated when the project started. The added value generated by the underground project includes the increased cost for real estate and rents due to the better accessibility by underground trains. This result leads to the conclusion that part of the value added by the rise in rents and cost for real estate due to the investment in transport infrastructure projects might be reclaimed by public authorities via a value-added based tax.

Table 2 – Three examples for estimates of the regional economic value added by transport infrastructure projects in Austria

| Investment project | Network length of extension | Regional economic value added per year in % of total investment cost | Reference |
|---|---|---|---|
| Motorway Ennstal | 78 km | ~ 59 % | [12] |
| Railway Südbahn | 160 km | ~ 10 % | [12] |
| Underground lines U3 and U6 in Vienna | 20 km | ~ 8 % | [13] |

## 3.2. Economic effect of induced and suppressed travel demand

The term "induced transport" is used for the increase in travel demand caused by improved accessibility, possibly due to transport infrastructure or organisational measures. Accessibility is determined by travel time and travelling costs from the users' point of view, which correspond to the generalised cost of mode users. An improvement in accessibility means a reduction of the generalised cost of mode users, e.g. faster travel speed or decreased travel cost such as reduced road tolls or fuel cost. An increase in the generalised cost of mode users has the opposite effect: it leads to suppressed transport demand. An induced travel demand means additional trips of transport users (trip generation), destinations in bigger distances (trip distribution), move of companies into the area and industrial location etc. due to the improved accessibility. This means that induced traffic has an impact due to the additional trips and the increased traffic volume (mileage travelled). The opposite is true for suppressed travel demand. By definition, a change of traffic volume due to a change of the modal choice or route choice cannot be considered as induced or suppressed travel demand.

A reduction of the generalised cost of mode users induces additional travel demand which means that part of the reduced generalised cost is used to increase travel demand. From the mode users' point of view this means a benefit or consumer surplus, otherwise they would not "consume" more transport. To express the consumer surplus in monetary terms the amount which mode users have to pay is subtracted from the generalised cost they would be prepared to pay. This corresponds to the triangle which is shown in figure 9 under the travel demand cost function. Figure 9 can also be used in the case of suppressed travel demand to show the consumer loss caused; in this case the arrows in figure 9 change direction. The induced or suppressed travel demand needs to be determined with the help of a suitable travel demand model. The consumer surplus or consumer loss caused by the induced or suppressed travel demand is estimated with the formula shown in table 2 [10, 15, 16]. Studies [10] show that in a cost-benefit analysis (CBA) induced or suppressed travel demand can account for nearly 10% of the overall benefit or more than 10% of the benefit due to the reduced travel time. If significant changes of the generalised cost of mode users are to be expected they have to be taken into account in any CBA. Moreover, one has to bear in mind that the induced or suppressed travel demand has other impacts, too, such as a change in traffic accidents or damage to the environment which should not be neglected. From the point of view of the mode user induced traffic due to improved accessibility is an individual benefit while the effect of induced traffic upon the environment and accidents has to be balanced against this. The opposite is true for a suppressed travel demand.

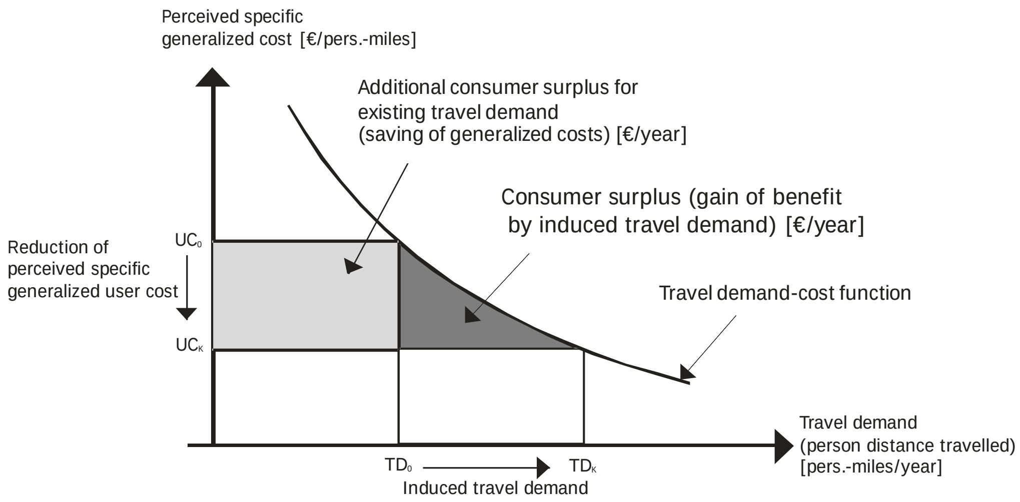



Figure 9 – Generalised cost function of travel demand and consumer surplus caused by induced travel demand

Table 3 – Formula to estimate the consumer surplus caused by induced transport demand

$$consumer\ \ surplus = 0{,}5 \cdot \left(TD_k - TD_0\right) \cdot \left(UC_0 - UC_k\right) \quad [€/year]$$

TD: induced travel demand

Reduction of perceived specific generalized user cost

## 3.3. Distribution of costs and benefits

The traditional cost-benefit analysis (CBA) shows only the net result of the benefit of any investment or measure but does not provide any information about the distribution of the monetary value of the benefits for the population concerned or the relevant protected goods. This information is important for any decision making to show who or what benefits from an investment or measure. This helps to disclose the social and economic impacts. The extended cost-benefit analysis (**e**CBA) does not only provide information about the net benefit but also about the distribution of costs and benefit; it shows the positive and negative impact upon each protected good or group of people concerned. In other words: winners and losers due to any measure become apparent and it is shown which protected goods are bound to benefit and which are not. This means that in all areas of action not only the net benefit but also the positive and negative impacts can be considered. Table 4 provides a hypothetical example for two alternative investments, an express road on the one hand and the extension of the existing road by a local bypass on the other which is based on a real project [10]. For the two alternatives the table presents the benefits in money-terms of the reduced travel time, the changed noise pollution and pollutant emission as well as the accidents, expressed as the difference between the two alternatives and the respective reference situation without any measure at all (do-nothing scenario). There are two columns on the right of the column for the net benefit; they show the positive or negative impact of the measures upon people and protected goods affected ("winners" indicated by a plus sign and "losers" indicated by a minus sign). The net benefit is the aggregation of the benefits of winners and losers.

Table 4 – Distribution of the benefits for various components of the cost-benefit analysis, depending on the positive or negative impact upon people and protected goods (positive values indicate a positive benefit, negative ones indicate costs, all expressed in millions of Euros; the hypothetical example is based on [10])

| | Scenario 1 extension by express road | | | Scenario 2 extension by local by-pass roads | | |
|---|---|---|---|---|---|---|
| Benefits due to reduction of [millions of Euros] | Benefit saldo | Positive („winners“) | Negative („losers“) | Benefit saldo | Positive („winners“) | Negative („losers“) |
| travel time | + 480 | + 498 | - 18 | + 16 | + 19 | - 3 |
| traffic noise | + 36 | + 44 | - 8 | + 30 | + 34 | - 4 |
| pollutant emissions | - 92 | + 15 | - 107 | - 22 | + 3 | - 25 |
| traffic accidents | + 125 | + 133 | - 8 | + 2 | + 2 | 0 |

The result can be interpreted as follows: Scenario 1 offers benefits of EUR 480 m due to a reduced travel time which is positive. But a closer look at this component shows that certain groups of people have to face longer travel times due to the measure taken which means cost of EUR 18 m (a negative impact). If groups of people are affected by this cost whose accessibility is already poor because they live in peripheral locations, this means a social disadvantage which should be considered in the decision making. In comparison, scenario 2 only offers benefits of EUR 16 m due to reduced travel times. But the cost for people who have to face longer travel times is quite low at only EUR 3 m. We see a similar picture for the three other components: there are losers for both scenarios who should not be ignored. To show the groups of people and protected goods which benefit or are disadvantaged one has to look at disaggregated data for travel demand and impact. In this case agent-based demand modelling might be helpful. Showing the distribution of cost and benefits is important additional information to the traditional cost-benefit analysis. The information available for decision making purposes thus becomes more complex and forces the decision-makers to think about distributive justice. One has to define objectives for this issue to be able to argue from this point of view in any decision-making process.

## CONCLUSION

Criticism and weaknesses of the traditional cost-benefit analysis for the assessment of investments in the transport infrastructure are evident. The development of new assessment and decision-making criteria for infrastructure planning is an attempt to overcome these weaknesses. With the development of the sustainable development analysis (SDA) and the extended cost-benefit analysis (**e**CBA) first steps towards a practical solution have been taken. The first applications of these tools demonstrate that they can be used in a real environment; their first generation has already had an impact upon national guidelines [10, 15, 16]. For the consolidation of these promising techniques further development is required.

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