THE CHALLENGE OF INCLUDING SYSTEM EFFECTS AND SYSTEM BOUNDARIES INTO THE ENVIRONMENTAL EVALUATION OF ROAD PROJECTS

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ABSTRACT

The benefits of a road and the predominant part of the implications arise from the operation. The focus regarding the assessment of these various effects increasingly has to shift from the one-dimensional examination of road lines to the holistic view of infrastructure networks.

The expansion of infrastructure and the expected benefits underlie a number of system effects. To begin with, feedback mechanisms exist, which are not taken adequately into account by the currently used (regional economic) models because of narrow spatial, temporal and causal system borders. Examples for that are countless: the omission of feedback mechanisms between infrastructure construction and mileage through the limitation on a single road section; the exclusion of intermodal alternatives or of the interactions between infrastructure and settlement structure.

Beside these system effects, development trends increasingly show logistic functions which are caused by saturation tendencies. These trends can be found in system parts or the whole system (depending on the system borders) due to capacity limits, limited resources or endogenous limits like saturation tendencies concerning motorization, travel distances or the disposable household budget for transportation. These phenomena can be traced back to ecological and biological feedback loops.

Therefore the choice of suitable criteria and indicators is crucial. Apart from the already addressed problems, it heavily depends on the chosen evaluation method. While the CBA focuses on the monetization of as many cost and benefit indicators as possible, the MCA depends on the choice of comprehensive key indicators. They must be able to describe sustainability and have to be cross-system, e.g. intermodal and including ecological, economical and social aspects. Furthermore, the key indicators should refer to development limits (distance-to-target indicators).

1. INTRODUCTION

Assessment methods are used in order to develop a value judgment of complex circumstances prior to political decisions. In this respect they are indispensable parts of examinations, comparisons, rankings, environmental impact assessments, economic transport studies, etc. They require a mental modelling of future conditions and their implications.

From an analytical point of view each assessment comprises three components

- The neutral model (scheme of interrelations, indicators)
- The value system (assessment criteria such as expert opinions, limits)
- The value judgment (e.g. expressed in nominal, ordinal or cardinal scales) as a result of the joining of model and value system

There are various instruments among the choices for this joining (check lists, preference matrices, rankings, etc. and/or certain rules such as aggregation rules, interpretations codes, guidelines, etc.). Mostly being complex, environmentally relevant issues are usually split into subsystems and are assessed in multiple steps. In order to get the total assessment, a forth step is needed – the aggregation weighting of the sub-assessments. In that, each assessment is influenced by countless variables. In the end, the efficiency of a measure is assessed on the achievement of objectives. The targets and goals increasingly come from outside the transport and settlement systems, being derived from human ecological limits, finite resources, and other global limits.

We have to be aware of the fact that all assessment methods are subjective. Problems arise from different perception and assessment by different individuals [1]. As a result of the necessary broadening of the system, all assessment methods are caught between the part of the system, availability of information and data and the assessment.

The use of formal assessment methods in their present form gives cause for criticism because of the multitude of deficiencies (as well as the possibilities for manipulation).

2. SYSTEM BEHAVIOUR AND ENVIRONMENT

2.1. The system and its behaviour

The transport and settlement system

A system can be broadly defined as an integrated set of elements that accomplish a defined objective. People from different engineering disciplines have different perspectives of what a "system" is.

An integrated transportation and settlement system characterized by an integrated set of interoperable elements which must be compatible within the systems structure and a lot of subsystems which is composed of hierarchical levels of components. In this way the basic elements of systems are resources, procedures (a set of rules govern the system to accomplish the defined goal of the system), data information and processes. In fact systems always have defined objectives and are working under a certain level of guidelines/ standards.

It is important for a system to adapt itself to its environment. A characteristic element of systems are feedback loops (e.g. between settlement structures and indicators of the transportation sphere, for example modal split). Beside these endogenous side effects there are also feedbacks between the system itself and the system's environment (exhaust gases, noise, and other negative and positive external effects, up to boundaries at the global level (e.g. greenhouse gas effects).

The transport and settlement system is, like all systems, a complex one and characterized by a multitude of feedback loops. This dynamic, which stems from the interaction of economy, society and transport system, cannot be understood without including feedback loops. To get a comprehensive understanding of the system it is crucial to understand the modes of action and to identify the variables and limits of the system. The variability of the transport system is limited in a way, that there are hard constraints such as the constancy of mobility and the constancy of the travelling time budget, which are established for some years now. Parameters which influence the attractiveness of the transport modes remain variable, such as speeds, prices, capacity restraints, etc.

The cumulative environmental impacts were first raised legally binding by the US National Environmental Policy Act in 1969 (NEPA, Sec. 150825). It dictates the consideration of cumulative environmental impacts for environmental impact studies.

The EC Directive (85/337/EC) 1985, which serves as basis for the current EIA act, in Appendix III (specification of documents, which have to be submitted by the responsible body) already mentions the description of cumulative impacts of a project. For the further characterization of interactions Appendix IV of the directive revised in 1997 states, that also “any indirect, secondary, cumulative (…) effects of the project” should be covered and explicitly names the inter-relationship together with the protective goods as “part of the environment”.

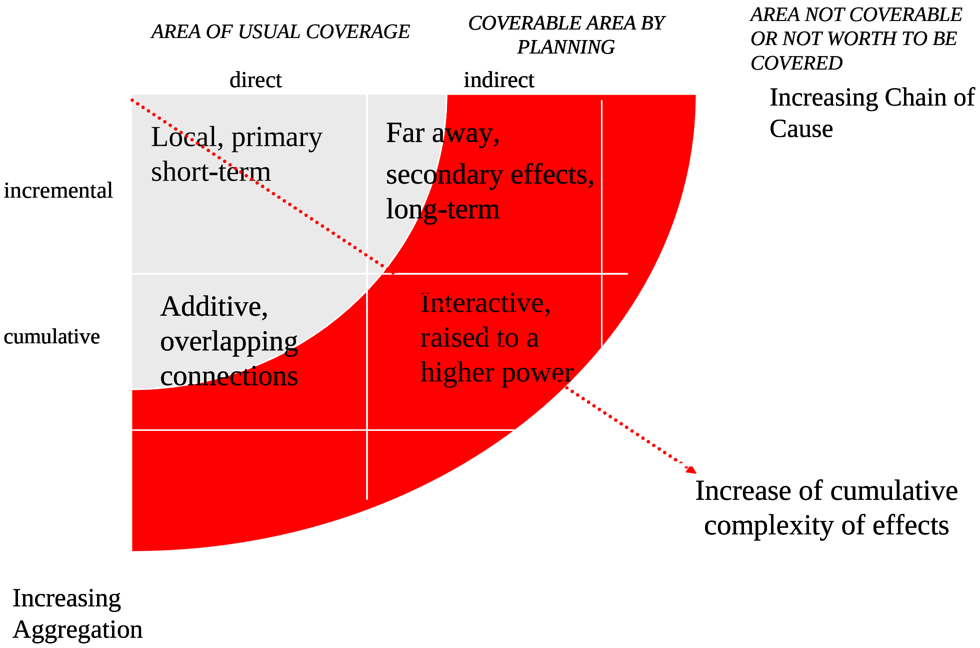

Figure 1 – Scheme of complexity of effects depending on the level of aggregation and the cause

The Amendment of the EIA-EC-Directive by the Council of the EU (1997) [2] intends to include “material assets and the cultural heritage” when dealing with inter-relations. Best results in the scientific research of cumulative environmental impacts were observed where cumulative impacts were studied in closely circumscribed ecosystems. Cumulative environmental impacts preferably emerge in agglomeration areas and depend on socio-economic as well as natural geographical factors.

Humans as part of the system

Figure 2 illustrates one means of classifying the human-environment system, incorporating well known development areas: environmental, economic, social, and institutional, as identified in the Brundtland report. The figure shows that individuals and society are a component of the natural environment, but that the natural environment is the basis upon which all human (and hence urban) development takes place. Thus both ecologic goals (e.g. limits on development posed by environmental concerns) and socio-economic goals (e.g. distribution of costs and benefits of actions amongst stakeholders) must be addressed. However, the importance of natural systems is poorly recognised in urban development, where economic (and to a lesser extent, social) theories of development predominate in assessment practice. This tension is very significant and is a fundamental issue to address if urban assessment practice is to properly address sustainable development.

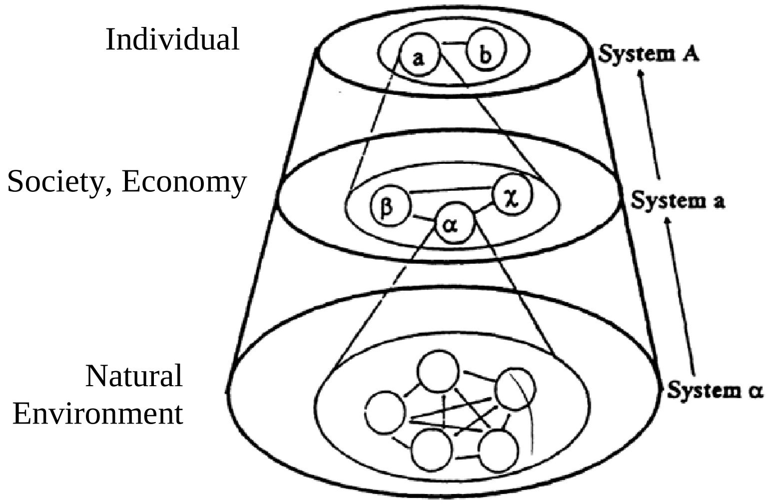

Figure 2 – The Human-Environment system

System indicators

Through its connecting function between „housing“, „working“, „leisure time“, „shopping“, etc. the transport system has an impact on the mobility behaviour, settlement structure, economic structure, lifestyles and ultimately on sustainability and quality of life. Therefore, the term “transport system” has to be understood comprehensively as mobility system.

The overall objective must be sustainability, with which the goals of the subsystems must be compatible. Current goals are often set only for specific transport modes; at best there exist cross-modal objectives such as modal split. The reference to sustainability within the transport system is still uncared-for.

In the wake of a step-wise opening beyond the present focusing on individual motorized transport, inter-modal alternatives as well as the development of settlement structure must be included. The economic and social systems are also influenced by the transport system and have to be regarded as essential basic conditions.

Constants and variables

When looking for useful indicators that describe the system behaviour we find constants (trips per day, mean travel time) which obviously are a result of biological and genetical human drivers. Indicators describing system behaviour variability are e.g. motorization rate, trip length or modal split. However, they are highly dependent on local circumstances as we can see when comparing cities and their surroundings or Asian and North-American cities. But these indicators are useless when trying to assess major issues such as quality of life, etc.

It is now recognized that an assessment of the sustainability including urban development requires a very broad perspective. Assessment practice to date has been largely focused on projects, and has been piecemeal and poorly suited to consider the consequences of actions and their alternatives in a way that is comprehensive and consistent with sustainability goals. Project level assessments have practical advantages in that they are conceptually simple making them easy to implement and to convey results to decision makers. However, their deficiencies are becoming increasingly apparent to decision makers who must reconcile the limitations of existing assessment methods with the demand from many stakeholders to make decisions which are consistent with sustainability objectives. Sustainable urban development requires that a much broader perspective is taken in assessment practice, so that a wider systems perspective is addressed, considering, as far as is possible:

- Environmental, social and economic impacts collectively;
- Indirect and secondary effects (positive or negative) of developments;
- Cumulative effects of developments (e.g. combined impact of multiple projects);
- Effects whose impacts are temporally delayed (e.g. experienced by future generations);
- Effects which have a long range, transboundary of global dimensions (e.g. green house gas emission);
- Impacts by different social groups, particularly those most disadvantaged;
- Impacts on critical natural systems;
- Development alternatives which only become apparent when a wider perspective is taken (e.g. evident at the strategic but not project level).

A similar, frequently cited comprehensive typology of cumulative impacts was developed as early as 1986 by Canadian and US-American environmental authorities [cf. 3].

It is also evident that restricting assessment to these very tangible elements is itself limited, and that sustainability assessment should ideally also address organizational issues such as:

- Information provision to concerned stakeholders;
- Active participation of affected stakeholders in the decision making process;
- How to communicate more effectively the assessment procedures with other industry groups and practitioners who also have sustainability assessment responsibilities;
- Organizational learning from the decision making process (e.g. how to improve the assessment and decision making process; how to ensure that decisions are taken quickly enough to avoid future negative impacts).

Thus a key goal problem facing urban sustainability assessment is to consider sufficient elements of the total systems such that the decision making process is consistent with the goals of sustainable urban development (including compatibility of a modified sub-system with the total system), whilst remaining practical to implement. The issue of practicality is clearly important, and is not just relevant in terms of cost. Practicality is also critical in terms of ensuring that decisions can be made quickly enough so that feedback's within the system can be recognized, considered in new assessments and decisions, and acted upon within the decision making process before damaging or irreversible adverse impacts occur. Thus there are conflicting demands for comprehensiveness and simplification.

2.2. Exogenous and endogenous boundaries

Beside these system effects increasingly logistical functions can be observed in the trends of transport systems in industrial countries, arising from saturation tendencies.

Parts of the system or (depending on system boundaries) greater combined systems show logistical functions due to their capacity limits, limits in resources or endogenous limits like saturation trends (e.g. in the motorization level or the trip length). These saturation tendencies can be explained by both ecological and biological control systems.

The mobility behaviour of road users is characterized by increasing mileage. This behaviour is determined by the general (legal, social, energetical, etc.) framework. A large proportion of the driving forces for traffic behaviour are unconscious. They are influenced by man's poor ability to grasp system effects.

Beside those effects which are immanent in any system as for example the law of diminishing marginal utility, increasingly new "system limits" for the mobility behaviour – ultimately derived from resource limits – arise.

A more rational aspect is introduced by the availability of financial resources of households for transportation (public and private transport) – for example as a share oft the CPI (Consumer Price Index). This share in fact does not reach the 20 percent threshold for a number of reasons. The combination of increasing purchasing power and decreasing or at least stagnating energy prices virtually encouraged the transportation sector. [cf. 4]

Until now, the significances of certain cost components in transportation have not been examined sufficiently. The last studies date from the time of the energy crises in the 80s. Merely the effect of fuel costs has been analyzed in these examinations, though. Today private households have to face increasing costs in heating (heating energy), food and other categories at stagnating household incomes. Finally, even if only the lower 30 percent of income groups are affected, it will pose a significant challenge for the whole transportation sector.

These endogenous constraints of growth have to be included in simulations by the proper choice of elasticities in boundary situations. The impact of increasing energy costs and an estimation of the arising consequences will be shown by analyzing data from the Austrian Ministry of Transport. Based upon this data we risk a glance at possible scenarios for the U.S. and Austria.

3. ASSESSMENT METHODS AND INDICATORS

The choice of indicators depends to a high degree on the used methods. The choice of criteria follows in the different formal conventional assessment methods varying demands. Using the CBA (Cost-Benefit Analysis) it is important to represent as many relevant effects of a measure as possible. These indicators used in the CBA should be able to be quantified and assessed by monetary units. The result is a multitude of criteria and indicators whose connections are not clarified. Further the CBA needs a summarizing approach which means a lot of indicators covering all quantifiable aspects have to be established. Problems are the question of supra-regional impacts, the question whether the criteria is effective at the cost-side or at the benefit-side.

MCA (Multi Criteria Analyse) on the other hand out of systematical reasons requires the restriction of the number of indicators and the identification of those indicators which explain the system behaviour best. The advantage of this method is that the chosen indicators do not have to be assessable in monetary units, but they can be system indicators (key-indicators) showing the state of a system. It is quite clear that criteria such as „modal-split“ or „energy“ are difficult to assess in monetary units in a greater system (if only comparing the differences between energy costs of electric energy and energy costs).

According to the European Commission [5] the following methods are available: matrices, computer simulations, GIS (Geographic information systems), CEA (Cost-effectiveness analysis), CBA (Cost-benefit analysis) and MCA (Multi-criteria analysis).

Concerning these methods clear restrictions were made. *„It was concluded that the use of CBA within the SEA process is not yet appropriate as there are not currently widely accepted and robust monetary valuations of environmental impacts“* [6, p.viii] or *„The use of cost-benefit analysis methods in SEA was examined but rejected“* [6, p.xiv].

The European Commission therefore recommends the MCA: *"It is recommended that multi criteria techniques be used as a way of comparing disparate impacts and alternative strategies"*.[5]

3.1. Assessment methods

The described formal assessment methods CBA, CEA and MCA can be used for various purposes. All can be applied for Environmental Impact Assessments (EIA) as well as Strategic Environmental Assessments (SEA).

Differences between EIA and SEA

The SEA should start early in the planning process and cover also plans and policies (!). That causes another time scale in the planning process, but the scales in general have to be widened in time (including e.g. effects on settlement structures) and space (loss of space). From an academic point of view this means a cumulating of effects and resulting uncertainty as well as that the most useful indicators are changing when widening the size of the viewed system.

Table 1 – Comparison of EIA and SEA

	Project - EIA	**SEA**
Object to examine	Single projects (e.g. street section)	Politics, plans and programs (e.g. traffic concept)
Target	Optimization of single projects of one traffic mode (choice of traffic lines)	Optimization of traffic mode crossing solutions
Examined alternatives	Variants of location lines incl. Zero option	Variants of traffic solutions including several traffic modes
Frame of introduction	Local effects near the location line	Regional and global effects incl. sum and succeeding effects in the traffic system
Analysis of environmental impacts	Specific, project related statements - High grade of specification - Small scale	Principle and strategic statements - Little grade of specification - Higher scale

Problems of common assessment methods

Assessment methods are used to simplify the decision making processes, or at least to make the process more objective and transparent, and imply some understanding of the system of interest and the structures and interactions within that system. The following components are common to assessment methods:

a) The system of interest;
b) The performance of output measures which are assumed to be objective or neutral;

c) Data describing the system and its components;
d) The value system, by which outputs are judged (e.g. expert opinions, threshold limits etc.);
e) An aggregation and/or weighting of component or partial assessments;
f) The value judgement, expressed on a nominal, ordinal or cardinal scale.

In attempting to interpret the results of assessment methods applied to a common system of interest, it is clear that difficulties of compatibility can arise in all of the above areas. Problems arise due to improper system demarcation (in space, time and causal system), missing system connections (feedbacks), poorly expressed quantitative exchange processes, missing or inadequate data, unknown influences and poor sensitivity testing and unknown effects or omission of threshold values. In addition to these systematic and methodical problems there are "human" problems arising due to different goals, differential influences exerted by experts and politicians. There is a problem of communication between different disciplines, general conflicts of interests, and a different world view or philosophy of life.

Table 2 - The Occurrence, Cause and Potential to Predict of Different Kinds of Effects (Source: [7])

	Direct effect	**Indirect effect**	**Cumulative effects**
Occurence	Over a short distance, and at the time of construction and in operation	Like a direct effect but at a later time and/or in farther distance	In general at a later time and/ or in a farther distance
Cause	Single project	Direct and indirect effect of a single project	Direct and indirect effect of a single project and effects of other activities
Possibility of prediction	Based on clear causal connections	Based on high probability	Based on high probability

Nevertheless, where assessments are applied to a common system of interest, or where systems overlap, there is an opportunity to gain additional information from interpreting the results of assessments collectively. In the case of urban sustainability where the system of interest is so comprehensive, this inevitably means that assessments will be conducted which are relevant to each other and the wider urban-environment system. However, when addressing the points (a)-(f) above it is exceedingly difficult to interpret the results of assessments within the context of the total system. In effect, differing values systems implicitly used in assessment methods, rules for aggregation, means of expressing results etc., all act to prevent the easy interpretation of the results of many assessments, conducted within narrow activity areas, and their contribution to the urban sustainability goals. One possible mechanism for encouraging iteration between results of urban sustainability assessments is through the integration of assessment methods with sustainability indicators, with the indicators acting as a common focus for interpretation of results from assessment methods.

3.2. The quality of indicators

Indicators of Sustainable Urban Development

Revising or developing assessment methods in order to address sustainability concerns is a significant challenge. To revise the many existing methods, or developing required new ones, is an even greater challenge, as the items addressed in (a)-(f) above must be addressed, whilst at the same time maintaining consistency with sustainability objectives.

Thus indicators arise from values, in that we measure what we care about, and they also create values, in that we care about what we measure [8]. They also symbolize the condition of a greater system, and whilst there are difficulties in developing effective indicators (see e.g. [9] for a critical review) they are now in widespread use within organisations with responsibilities for delivering sustainability (e.g. public agencies), and many others whose primary responsibilities lie elsewhere (e.g. large corporations). Thus assessing sustainable development performance is no longer seen as a task only for government, but one that can usefully be undertaken at many levels, including corporately or within specific activities and professions. Such indicators are powerful and influential aids to decision making, but like statistics, they can be used inappropriately, or even be used to mislead and misinform. For these reasons indicators are frequently contentious and often debates focus on the nature of the indicator rather than on the information that it is meant to convey.

These variables are in widespread use in appraisal of road traffic policies, and are simple to quantify. However, in terms of sustainability assessment there are clear problems. Firstly there is considerable redundancy, with many issues being addressed by more than one criterion, as Table 3 shows, analysing twenty Austrian traffic appraisal projects.

In current practice, the need to quantify as well as the availability of data lead to the use of simple values like length, space, velocity, time or traffic volume.

Table 3 – Redundancies of indicators

Lenght (distance)	Barrier effects, flora and fauna, areas of protections, traffic quality, ground water, noise
Space	Waste of space, noise, exhaust gases, areas of protection, impact while constructing
Speed	Barrier effects, travel speed, traffic safety, driving comfort
Time	Shocks, travel-time, velocity, barrier effects, traffic quality
Traffic volume	Barrier effects, diversion effectiveness, traffic volume, waste of energy

This process of revision and development to address sustainability issues have already been performed, at least in part, for performance indicators, used in many activity spheres, to produce sustainability indicators. This process is much simpler than that for assessment methods, as only the objective criteria must be addressed (the indicator), and not the process of deriving the value of that objective criteria (the assessment method). Indicators are convenient tools for synthesising and presenting data, and may have the following objectives:

- Synthesising masses of data;
- Showing where we are in relation to desired states;
- Demonstrating progress towards goals and objectives;
- Communicating current status to users so that effective decisions can be taken leading us towards agreed-upon goals.

To meet these objectives, an indicator should be relevant and scientifically valid, sensitive to change across space and/or groups, sensitive to change over time, consistent, understandable, measurable, have an appropriate data transformation, and be reproducible. Such indicators of sustainable development have been seen as one tool by which sustainable development goals can be advanced. They do this by:

- Fostering the debate and consensus on what the broad sustainable development goals are. This is clearly critical as sustainable development is recognised as a "fuzzy" concept;
- Forcing assessment to take place on a holistic basis, but allowing users to assess parts of that system in detail, whilst encouraging internal consistency with the remainder of the system; and
- Expressing current status with respect to fundamental ecological limits.

Table 4 - Characteristics of Selected Criteria Used in Evaluating Traffic Management Plans in Germany/ Austria; Source: [10]

Criterion	Common Target Values	Alternative Target Values				System widening (related indicators.)
Barrier effects/ Cutting areas	length	velocity	Number of vehicles	Waiting period		length per space density of network
Waste of space	length				area	Areas per space
Flora and fauna	length				Number of endangered species	Biodiversity per space
Areas of protection	length				space	area (or number) per space
Traffic quality	length				time	-------------
Time-mean speed		velocity				-------------
Traffic effectivity			number of vehicles			Traffic volume
Travel time				time		-------------

More fundamentally, there are problems with these criteria as they do not adequately address sustainability issues, in that it is not apparent how such criteria link to the three widely accepted pillars of sustainability, namely economy, society and environment. There are no obvious relationships, for example, drawn to ecological limits (assimilative capacities for emitted pollutants for example), or assessment of impacts on particular social groups, for instance. Were these to be addressed, there would still be a need to integrate these criteria so as to facilitate comparison of alternatives.

Requirements for indicators

The used methods themselves, even the MCA are not intended to be modified for sustainability and strategic aspects. So it is necessary to find indicators explaining the system behaviour on an integrative level and to weight them in a right way (out of aspects of sustainability).

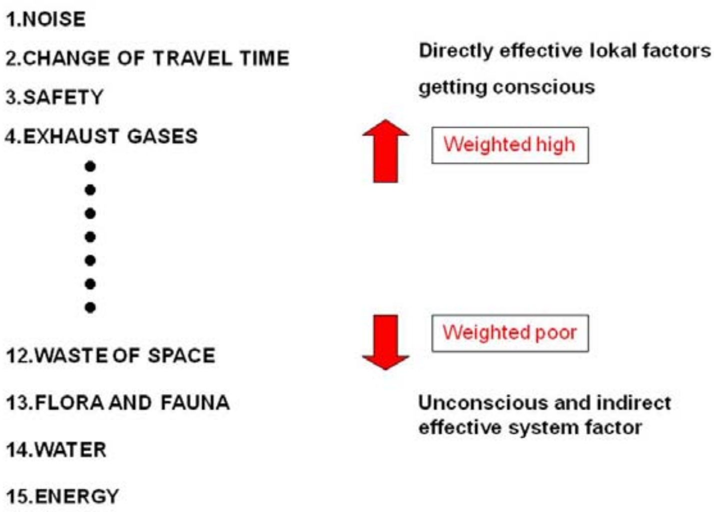

Figure 3 - Ranking of indicators according to their weight in a MCA

As we can see the weights of indicators and criteria have a strong dependence of the local acceptability and visibility. System factors with relationship to long-time scales or global effects and barriers are weighted poor (Figure 3).

Indicators depend on the system size

The most reasonable indicator is changing with every step of widening the viewed system. Using assessment methods for instance to assess a new bypass it is usual to include only this new bypass-section into the procedure (Step 1, see Table 5). At this stage we can work using an indicator like number of vehicles.

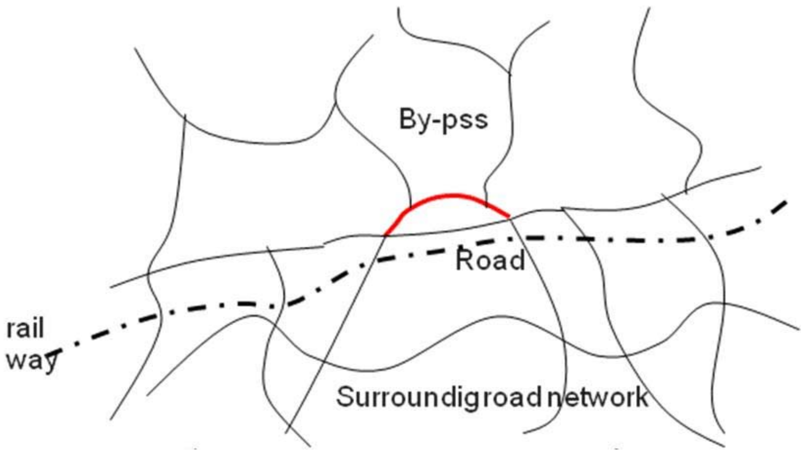

Figure 4 - Schematic infrastructure network (roads, railway) to include into environmental assessment procedures concerning a settlement bypass; Source: [7]

Step 1 – Exclusive consideration of the bypass line
Usually the assessment and the decision making process concentrate on a single road section (e.g. a bypass road).

Step 2 – Including the former road
At the least it is necessary to widen the viewed system to include the "old" through road due to the fact that the mobility demand is satisfied in case of a bypass by two roads. At both road sections noise problems, maintenance costs, exhaust gases and so on will be generated. In such a wider corridor system the indicator has to be changed using an indicator like traffic volume.

Figure 5 – Step 1

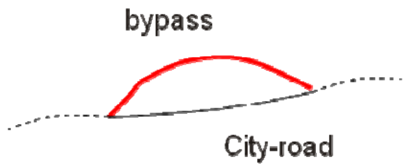

Figure 6 – Step 2

This small step of including the old road already yields significantly different targeted returns.

The implementation of a corridor approach and the inevitable necessary widening of the system can be seen one small part of the problem of internalizing external effects.

Table 5 - Seven steps of enlarging the viewed system together with changing “best fitting” indicators and effects on the aspects “time”, “space” and “causalities; Source: [7]

	Indikators	**Time**	**Space**	**Methods**
1	Number of vehicles	Status- quo Simulation	Street section	counts in cross sections
2	Traffic amount	Mostly Status- quo Lineare Forecasts or Motorisation rate	Corridor	counts in cross sections Calculations
3	Traffic amount	Forecasts or Motorisation rate	Borders by Distributions of trip lenght	counts in cross sections Calculations
4	Modal-split	Szenarios	Distributions of trip lenght „ecological backpack	Simulation results, Trip chains
5	Modal - split	Szenarios	Distributions of trip lenght „ ecological backpack,	Simulation results, Trip chains
6	Modal- split (Energie)	Szenarios	Settlement or regional areas	Models
7	Energy, CO_2	Szenarios	global	Models

Step 3 means to widen the viewed system including the surrounding network (Step 3), step 4 to include alternative modes like railway. The next step means to extend the time scale regarding the development of the surrounding network (Step 5) and the development of the settlement structures (Step 6). Beginning from the step 4 a comprehensive indicator has to be based on modal-split or at least on person flows. Targeting sustainability it will also be necessary to include global aspects (global thinking, local acting) (Step 7) especially regarding global borders of development. At these levels energy might be a better indicator then modal split.

The current approaches of city and regional planning state that there is a need to accelerate the speed between functions at a local level as well as within regions or even continents to raise accessibility of areas and by that to gain advantages in a free competition. This assumption, however, leads to the separation of functions and the spreading of settlements followed by considerable negative effects on ecological as well as social aspects.

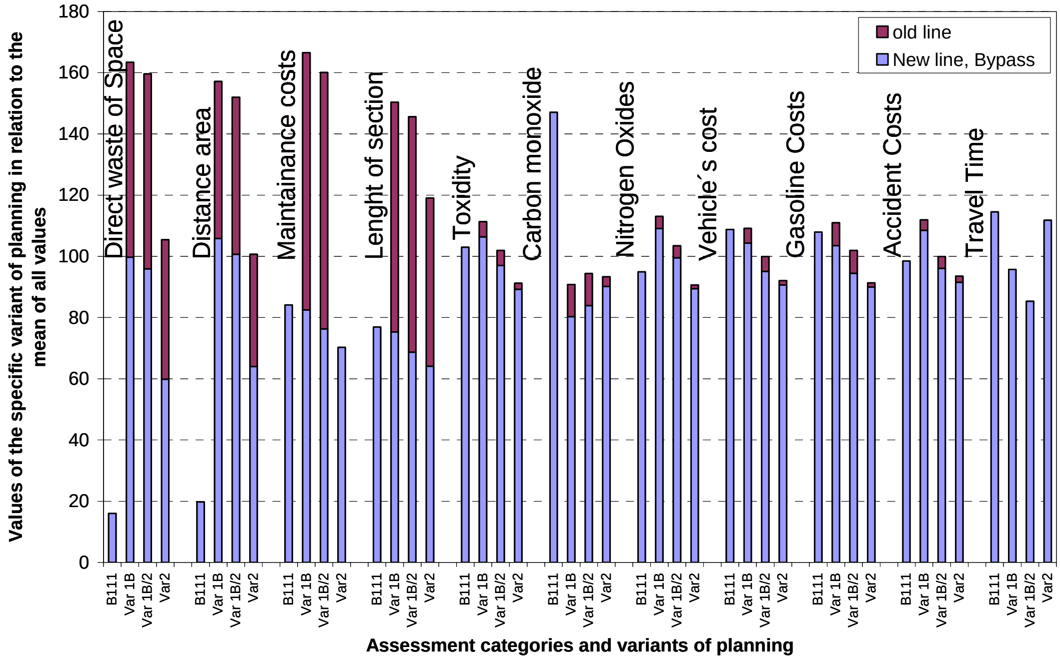

Figure 7 – Ratio of targeted returns for the example of the road construction project B111 (“Drautalstraße”), Carinthia, Austria; Source: [11]

Example of the problem: The CBA (Cost-Benefit Analysis)

The CBA is an analogical implementation of the economic investment calculation on those allocation decisions, which are not taken by the market, but are subject to political-administrative processes. It is a method of selection of public projects. The main decision criterion is the maximizing of the “wealth of the society as a whole”, in a formal analogy to the maximizing of profits of companies. An operational scheme of the CBA can be found in [12].

The most serious problems when trying to grasp costs and benefits emerge from supra-regional impacts as well as from the dilemma when components entail both costs and benefits (e.g. consequential costs of accidents). This question, whether specific aspects of a project are to be judged positively or negatively, is a central problem (cf. also assessment of travel time).

A further challenge lies in the determination of prices. The interactions which have to be taken into account increase with the widening of the system. From an economic point of view they can be classified in direct, indirect and intangible effects. For all of them there are quantifiable and not quantifiable costs and benefits (see Figure 8).

The CBA usually comprises only the direct, quantifiable costs and benefits, thus analysing a cropped part of the reality and producing a pseudo-accuracy, which has nothing to do with the reality whatsoever. Scientific discourse emerges from the (grey) area between quantifiability and non-quantifiability.

- Direct (primary, internal) cost and benefit-components: including direct beneficiaries (benefits) or harmed (costs). E.g. benefits for road users, but also disadvantages for residents such as noise, exhaust gases, etc.
- Indirect (secondary, external, spillover) cost and benefit-components: including the costs and benefits of those not directly affected by a project; e.g. advantages or disadvantages for a region. Such external effects also arise from public (state-)

activities and constitute a considerable part of the components of a CBA. Examples are ozone, or regional economic effects.

- Intangible (tertiary, meta-economic) cost and benefit-components: in contrast to the indirect costs and benefits, the parties concerned can hardly be identified; e.g. impairment or destruction of scenery or cityscape, generally the impairment of esthetical values. There is a smooth transition between indirect and intangible costs and benefits as they are often correlated: e.g. an urban motorway entails a displacement of economic and social activities, (possibly) causing segregation and social aridification of whole districts, but independently it influences the cityscape.

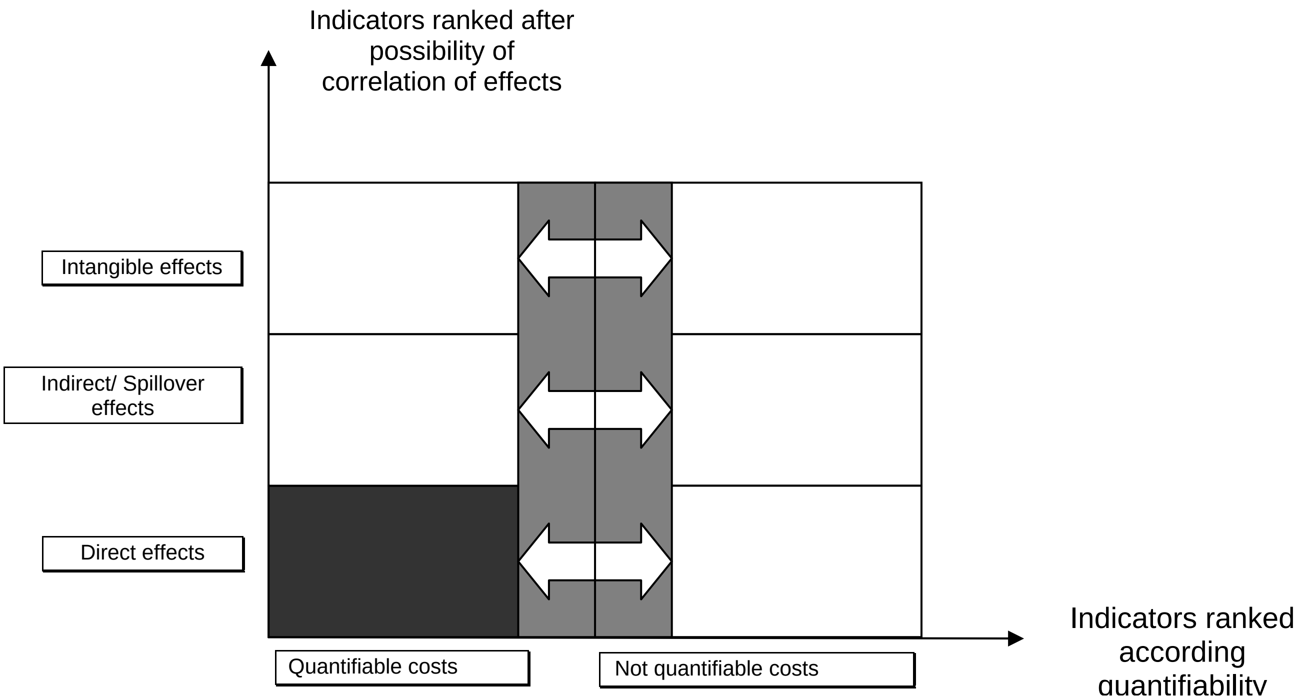

Figure 8 – Scheme of cost and benefit-components concerning their quantifiability and the kind of effects on parties concerned; Source: [7]

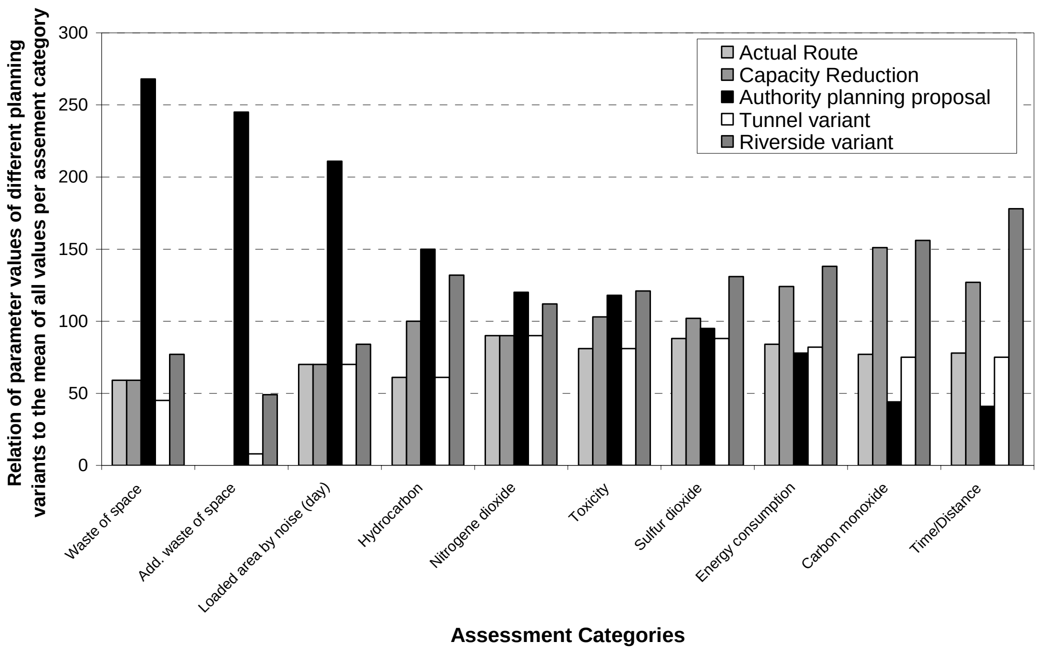

Figure 9 - Ratio of parameter values of different planning variants compared to the mean of all values per assessment; B 111 („Drautalstraße“); Carinthia, Austria; Source: [11]

Figure 9 shows the weighting and by that the underlying targets. The alternative planned by the province of Carinthia is oriented towards the reduction of travel times following the idea of increasing accessibilities. Simultaneously other parameters such as waste of space or specific exhaust gas components are maximized.

Accessibility

One of the fundamental indicators of traditional road construction is accessibility (often quantified as ‘travel time reduction’). It is derived from operational approaches and location theory. Decisions concerning the high-level road network usually are based on studies using potential-based accessibility approaches. In most cases the benefits are solely described as time advantages. However, time advantages can only insufficiently depict accessibility advantages and their feedbacks, e.g. intermodal compensation or settlement structure development.

Central European Examples

A lot of Environmental Impact Assessments (EIA) had been carried out in Austria. Many of them were carried out in form of a MCA. MCAs have the advantage to force the assessor to deal with key- indicators and by that with the system behaviour.

The European Union has recommended Multi Criteria Analysis (MCA) instead of Cost Benefit Analysis (CBA). The motivation was that the cost components of CBA are still not stable enough.

On Austrian and German examples however the wide range of results using MCA and its different indicators (criteria), different weights and different system borders can be shown [7].

Usually Environmental Impact Assessments work with a lot of indicators describing spatial and environmental aspects as well as criteria describing traffic-related and financial aspects.

Normally the assessment method results in a recommendation of a new infrastructure as proposed by the government. These streets as proposed normally are orientated on reachability aspects and are weighting speed advantages rather high. (As described the daily travel time is a constant so higher speed is converted into increasing trip lengths. There is no time saving in the system. Aspects like that will have to be regarded in a future sustainable system.)

In fact the used indicators are completely unorganised and methodically not verified. Actually a lot of those unorganised used aspects and indicators will have to be removed and replaced by a few intelligent key- indicators if we aim for sustainability. The effect of a multi criteria approach is much more differentiating than the results of a so called sensibility analysis usually are figuring.

Table 6 shows an example of MCA results for a bypass in Austria (Carinthia). The alternative (1B/1) as proposed by the government of Carinthia was ranged at the second place, for example the current situation (alternative 0) was primary ranged at the tenth place.

Range	Scenario	SIM 1	SIM 2	SIM 3
1.	1A	E	**0**	**0**
2.	1B/1	2A	2A	E
3.	E	2	E	2A
4.	2A	1A	2	3B
5.	2	1B/1	3B	2
6.	1C	1C	3	3
7.	3B	**0**	3C	3C
8.	3C	3B	3A	3A
9.	3A	3C	1A	1A
10.	**0**	3	1B/1	1C
11.	3	3A	1C	1B/1

Range	Scenario	SIM 1	SIM 2	SIM 3
1.	9	9	9	**0**
2.	10	10	5	1
3.	5	5	1	5
4.	6	6	10	9
5.	1	1	**0**	2
6.	2	2	6	6
7.	3	3	2	3
8.	4	4	3	7
9.	7	**0**	4	10
10.	**0**	7	7	4
11.	8	8	8	8

Table 6 - Example of a ranking of alternatives (Projekt- Planfall), Federal road “Drautal, federal state of Carinthia, Austria”, Source: [7]

In a first approach (SIM 1) it is necessary to eliminate those indicators dealing with constants in a transport system, which means we have to remove criteria which will be compensated by special, temporal or causal system effects. Further all criteria have to be removed which show a reference to unexaminable (political) targets or short-time effects (e.g. Impairment while constructing). Further a review of criteria referring to redundancies has to be done, aiming the reduction of the number of criteria and to point out key-indicators.

In a second step (SIM 2) the indicators have to refer on a corridor approach, at least (see chapter 4.2) including the unburdened throughroad and by that to refer to a wider special system.

In a third step (SIM 3) the weights for different aspects have to be changed aiming higher weights for system effects (e.g. diversity of species or non renewable energy)

The result of the simulation shows that there are great differences regarding the ranges of the different planning alternatives. This is completely in contrary to the usually stated predictions that results of assessment methods are rather stable against changes of indicators and weights (sensitivity analysis).

4. CONCLUSIONS

Indicators and assessment procedures aiming to describe broader systems and finally sustainability are both areas in which considerable development work has been done, but where developments have not yet fulfilled their potential. Sustainability indicators are in widespread use, particularly at government and local authority level, and they are increasingly being developed to meet the needs of a very wide range of urban activities, users, and scales. However, they remain "weak sustainability" instruments, in that few adequately address core sustainability principles. Sustainability assessment methods are perhaps less well developed than indicators, with conventional methods such as CBA and MCA struggling to gain acceptance as credible sustainability tools, whilst new methods designed explicitly to address sustainability criteria have not yet been widely accepted by assessment practitioners. In this respect the weak possibilities of perception by human beings especially in identifying borders of development, differences in space and time as well as realizing causalities play a considerable role weighting problems.

There is clear scope for developing new and improved sustainability indicators and assessment methods. However, these developments should not take place in isolation, as it is recognised that there is clear added value in developing them synergistically. Such integration between indicators and existing appraisal methods remains relatively rare, although there are notable exceptions. The EU Strategic Environmental Assessment directive, for example, notes that cost-benefit analysis is not the best option for appraisal, and presents opportunities for integration of indicators and methods.

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