A sustainable transport structure as a problem of choosing intelligent indicators

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Abstract

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

The raising of speed in the transport system therefore should be more sophisticated, since at the local level accessibility is the main indicator to describe mobility. Mobility is defined by the number of trips per day, independent of the modes of transport used, i.e. also walking. Defined in this way, mobility is rather a constant because of limited purposes of trips.

However, there are two possibilities to reach a “mobile” society. On the one hand we can attempt to increase velocity to reach destinations even far away (which is not sustainable because the short term effects of reducing travel time are compensated by a lot of feedbacks within short periods as well as long term changes of settlement patterns). The alternative approach is to keep the destinations of necessary trips to a short distance, and only by that, can the operation possibilities of alternative modes of transport be optimized.

Within a complex system, built by a lot of feedback loops, the human ability to perceive such system effects is overstrained. Therefore it is useful to orientate on proved ecological principles.

In analysing complex systems, we have to bear in mind that human beings are preconditioned to assess directly effective local factors which are consciously perceived by the individual (e.g. time savings, noise, safety) as rather high. On the other hand, indirect effective indicators (such as energy, flora and fauna, waste of space) which are perceived unconsciously are rated very low. The effect of this weighting problem can be demonstrated on simulations of assessment procedures.

Keywords: MCA- multi criteria analysis, key-indicators, sustainability, mobility constants, human ability of perception.
1 Introduction

Mobility and the transport system show close feedbacks with aspects like nature, quality of life, social system, economy, settlement structures and even culture. The result of the search for solutions of transport problems for nearly half a century seems to be not only without success but the measures were in many cases counterproductive. Only a few transport problems were solved, but a lot of new problems were created such as, congestion, noise, exhaust gases, problems to local economy, damage of nature and so on.

It appears more and more clearly, that transport systems only can be assessed in a broader context. The difficulties of doing this lay in the poor ability of perceptions of human beings. Especially the so called “apriories” of Kant (=the main problems of experience) “time”, “space” and “causalities” – and derived criteria - also are the main problems within the transport system.

Human beings are adjusted to short periods of assessment, rapid changing rates, manageable sizes, small social groups and limited ability of sensual perception. It is quite clear that the enlargement of an assessed system also comes along with increasing cumulative complexity of the system. Beside the direct effects also indirect and cumulative effects caused by a lot of feedbacks have to be taken into account. It is also clear that the possibility of prediction will change in an enlarged system from widely clear causal connections to approaches working on higher probabilities.

In a complex environment it is necessary to find the best fitting indicators to describe the behavior of the viewed system. These indicators might change with every step of widening the system. Two problems are arising:

- The poor human ability to perceive system effects
- The methodical problems of verifying cumulative effects caused by feedbacks

Figure 1: Information gathered by humans work on any level from the molecular level up to the cultural level, [1].
2 The human ability of perception

The problem of perception and learning follows a spiral process. Out of the level of expectation and the given experience, every new experience changes the expectation and every new expectation leads to new sources of experience. Figure 1 describes the spiral process as working on any level from the pre-cellular level (by flowing of energy) up to cultural levels (Objectives of groups). Only a few levels are conscious ones, powerful levels in contrast are working unconscious. It is necessary to keep that fact in mind, because these weighting procedures are dominating as well the perception as also the weighting processes on any level of an assessment procedure.

The following components are common to all assessment methods. On any stage weighting procedures by humans are carried out. That means there is no objective or value-free assessment method possible. [3, 5, 6].
(a) The system of interest;
(b) The performance of output measures which are assumed to be objective or "value-free";
(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 a complex system however human beings are preconditioned to assess directly effective local factors, which are consciously perceived by the individual (e.g. time savings, noise, safety) are rated high. On the other hand, indirect effective indicators (such as energy, flora and fauna, waste of space), which are perceived unconsciously, are rated very low. The effect of this weighting problem can be demonstrated on a lot of Environmental Impact Assessments (EIA) carried out in Austria and Germany [2].

3 Problems of verifying indicators in a complex system

3.1 Constants and variables in the transport system

There are a lot of dogmas circulating in the scientific and professional world, like increasing mobility, time savings by increasing mobility or freedom of modal choice.

Out of biological reasons the travel time is a constant, and the number of trips also remains rather constant. What we are changing is the modal-split.

The raising of speed in the transport system should therefore be seen more differentiated. On the local level the accessibility is the main indicator to describe mobility. Mobility is defined by the number of trips per day, independent of the modes of transport used, also walking is considered. Defined
in this way, mobility is rather a constant because of limited purposes of trips. However, there are two possibilities to reach a “mobile” society. At first we can attempt to increase velocity to reach destinations even far away (which is not sustainable because short time effects of reducing travel time are compensated by a lot of feedback loops within short time as well as long term changes in the settlement patterns). The alternative approach is to keep the destinations of trips a short distance. In doing so, the operation possibilities of alternative modes of transport can be optimized.

3.2 The choice of intelligent key-indicators

Intelligent key-indicators have to describe the behaviour of the system as representative and repeatable. They are symbolizing the state of a greater system network which means that connections and feedback must be clear. The selected values should be integrative and if possible distance-to-target indicators.

In current practice, accelerating speed seems to be one of the main targets of transport planning as well as city and regional planning. Velocity is in fact a key indicator to describe causalities in a transport system. A lot of indicators can be derived from the key-indicator “velocity” as the figure 2 shows. There are, for example, strong connections with the increasing number of vehicles followed by increasing waste of energy, health problems, exhaust gasses and noise but also effects appearing inherent to the system like increasing trip lengths (due to the constant mobility time) and resulting increasing traffic volume followed by the “inherent necessity” to build new roads and a reaction of settlement structures.

![Figure 2: System-effects related to velocity on a road network, schematic causal loop diagram, [4].](image)

But there are also other key-indicators like “modal-split” describing the system behaviour in a useful way.
3.3 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 2). At this stage we can work using an indicator like number of vehicles.

![Schematic infrastructure network](image)

**Figure 3:** Schematic infrastructure network (roads, railway) to include into environmental assessment procedures concerning a settlement bypass, [2].

**Table 1:** Seven steps of enlarging the viewed system together with changing “best fitting” indicators and effects on the aspects “time”, “space” and “causalities.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Time</th>
<th>Space</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of vehicles</td>
<td>Status-quo Simulation</td>
<td>Street section</td>
</tr>
<tr>
<td>2</td>
<td>Traffic amount</td>
<td>Mostly Status-quo</td>
<td>Corridor</td>
</tr>
<tr>
<td>3</td>
<td>Traffic amount</td>
<td>Lineare Forecasts</td>
<td>Borders by</td>
</tr>
<tr>
<td>4</td>
<td>Modal-split</td>
<td>Szenarios</td>
<td>Distributions of trip length</td>
</tr>
<tr>
<td>5</td>
<td>Modal-split</td>
<td>Szenarios</td>
<td>Distributions of trip length</td>
</tr>
<tr>
<td>6</td>
<td>Modal-split (Energie)</td>
<td>Szenarios</td>
<td>Settlement or regional</td>
</tr>
<tr>
<td>7</td>
<td>Energy, CO₂</td>
<td>Szenarios</td>
<td>global</td>
</tr>
</tbody>
</table>

At the least it is necessary to widen the viewed system including 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 (Step 2) the indicator has to be changed using an indicator like traffic volume.

We have to widen the viewed system step by step including the surrounding network (Step 3), the alternative modes like railway (Step 4). 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 wise indicator has to be based on modal-split or at least on person flows.

In the future it also will be necessary to include global aspect (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 separation of functions and the spreading of settlements followed by considerable negative effects also on ecological and social aspects.

### 3.4 System point of view versus individual point of view

There is a clear difference between a system point of view and an individual perspective. Comparing constants and variables in the transport and settlement system with individual perceptions the result is that there is no possibility to draw a conclusion out of the individual sphere to system behaviour. While human beings seem to spare time by accelerating speed on new roads this time spare effects will be compensated in a system by increasing trip lengths (due to constancy of travel time per day)

<table>
<thead>
<tr>
<th>System point of view</th>
<th>Individual point of view</th>
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<tbody>
<tr>
<td></td>
<td>objective</td>
</tr>
<tr>
<td>Time</td>
<td>Constancy of time</td>
</tr>
<tr>
<td>Space</td>
<td>Depends on speed</td>
</tr>
<tr>
<td>Energy (Causality)</td>
<td>Total energy amount</td>
</tr>
</tbody>
</table>

The poor ability to perceive the effects in time and space as well as resulting energy amounts (besides increasing costs of energy) leads to an enlarged system without additional values for individuals. In contrary a lot of functions (working places, local supplies) are displaced into farer distances. The decreasing abilities to cover local supplies are only one of the results.
4 Multi criteria analysis and the weighting problem

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 [2].

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 3: Example of a ranking of alternatives (Projekt-Planfall), Federal road “Drautal, federal state of Carinthia, Austria”, [2].
Table 3 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.

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.

In a second step (SIM 2) the indicators have to refer on a corridor approach, at least (see chapter 3.3) 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 contrary to the usually stated predictions, that results of assessment methods are rather stable against changes of indicators and weights (sensibility analyse).

In fact MCA analyses show a broad range of results using indicators aiming sustainability in comparison with traditional approaches. The ranges are so broad that there cannot be comprehensible, reliable results. This result of a certain arbitrariness of assessment methods must lead to efforts aiming at scientific based choices of criteria.

5 Result and conclusion

Regarding the complexity of systems there has to be great attention to a validated choice of the system assessed. In this respect we also have to bear in mind the weak possibilities of perception and the precondition of humans adjusted to short periods of assessment, rapid changing rates, manageable sizes and small social groups. As a result, directly effective local factors like noise, which are consciously perceivable by human beings, are rated rather high. On the other hand, indirect effective indicators, which are perceived unconsciously, are rated very low.

It is scientifically possible to include system effects and (global) borders to the assessment procedures, but this approach seems to be doomed because of human problems of perceiving, weighting (and acting). Within a complex system with feed back loops, the human ability of perceiving such system effects is overstrained.

Holding that in mind it might be useful to orientate on proofed ecological principles. Analysing ecologic systems there are a few characteristics and principles given which we should adopt to man-made systems. Those principles are variety and cooperation, maximum efficiency with a minimum of energy
amount, self control (control of growth by feed-backs), closed causal loops (recycling), complex, long life-cycles, high degree of information, networks of self-regulating interactions and regionalization.

References

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