Presented at:: European Transport Conference ETC'05, 3.-5.10.2005, Strasburg

"ARE WE MOVING IN THE RIGHT DIRECTION?" MULTI-CRITERIA ENVIRONMENTAL IMPACT ASSESSMENT WITH TERM INDICATORS

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ABSTRACT

This paper systematically reviews two questions central for environmental impact assessment: What are the relevant environmental impacts of transport? And, are they improving, i.e. what is their overall assessment? We focus on a European approach as illustrated by the 'Transport and Environment Reporting Mechanism (TERM)' of the European Environment Agency.

Although this system is in practical operation since 1999, a systematic review of the TERM indicators still identifies numerous points for improvement: Redundant, non-pertinent and non-representative indicators can be eliminated and reduces data demand by a factor of three. Overview can be improved by a classification according to environmental impact categories. These criteria allow to streamline the current twenty-four indicators to a maximum number of seven key indicators.

For the first overall assessment of environmental impact of road transport in Europe we apply the ELECTRE III method. This ordinal multi-criteria assessment method allows to systematically identify a diverse range of individual evaluations, that still ascertain that the environmental performance improves from 1990 to 2010 in the European Union (EU15). However, the data uncertainty for air pollution and noise indicators needs to reduced significantly and indicators for land take and fragmentation should be redefined to make them sensitive to temporal change. Otherwise, these indicators cannot be sensibly interpreted and efforts are wasted.

Our systematic analysis provides arguments to focus further efforts on a reduction of fuel consumption and minimal infrastructure construction in order to improve the environmental performance of road transport in Europe.

1 INTEGRATED ENVIRONMENTAL ASSESSMENT OF EUROPEAN ROAD TRAFFIC WITH TERM INDICATORS

"Are we moving in the right direction?" is TERM's key question on the environmental performance of transport in Europe and, consequently, of European transport policy. However, a comprehensive answer has been missing since the first publication of the 'Transport and Environment Reporting Mechanism (TERM)' by the European Environment Agency in the year 1999 (EEA 1999). There are the fundamental problems, if, how and by whom a relative importance of the different environmental impact categories is assigned, and if a positive performance in one category can compensate for a negative performance of another? Second, the environmental impacts are by their very nature heterogeneous and therefore hard to compare. A third, technical problem is simply lack or poor quality of data. But what at all are transport's relevant environmental impacts?

Here we first review the indicator set of the European Environment Agency to come up with a proposal of a maximum of seven key indicators representing the most important environmental impacts of transport. These indicators are, for a second step, the basis for a systematic impact assessment. This provides both a methodologically sound answer to the question of overall environmental performance and further lessons about indicator selection and interpretation.

Indicators are a convenient way to summarise and highlight issues of importance. Here we take the example of the TERM project (EEA 1999ff.). This project distinguishes itself because it has an integrative approach, Europe-wide data are available and the indicators are used in policy assessments. We are not concerned with proposing an *ideal* set of indicators; on the contrary, we analyse what conclusions can be drawn from the *real-world* indicators and data.

A first limitation is, that despite its aspirations, real TERM data are only given for road transport and notably aviation and shipping impacts are left aside. Furthermore, so far lack of structure encumbers a straightforward interpretation.

Classification of indicators and completeness check

The completeness of the TERM indicators is verified by comparison with the impact categories of both, SEA directive of the European Union (DIR 2001/42/EC) and the Life Cycle Methodology as it is internationally verified (DIN EN ISO 14040ff). The originally twenty-four environmental indicators can be assigned to nine comprehensive environmental impact categories covering all currently discussed issues of importance.

Elimination of redundant and non-pertinent indicators

Not all indicators are of equal importance. Each impact category and all original indicators have been analysed in detail (Borken 2005). We propose a maximum of seven impact categories for consideration in a Strategic Environmental Assessment of road transport, with one representative indicator each (Table 1). The selection results from the following criteria:

- The indicators must not be redundant, therefore choose
    - either final energy consumption or emissions of climate gases to represent the impact category climate change,
    - either exposition to or annoyance by traffic noise to represent the impact category noise;
    - either traffic's emission of air pollutants or the share of traffic to air pollutants ambient concentrations to represent air pollution impacts;
    - either fragmentation by traffic infrastructure or traffic's contribution to eutrophication and acidification to represent biodiversity impacts.

- The indicators must be specific for transport as cause *as well as* pertinent for a relevant environmental impact. As their environmental importance is not reasoned, the indicators
  - ‘proximity of traffic infrastructure to nature reserves’,
  - ‘number of end-of-life vehicles and tyres’, and
  - ‘number of discovered oil slicks’

  are not included in the assessment.
- The road traffic must be a relevant cause. Here we demand at least 5% contribution to the total impact. Below this margin are
  - emissions of ozone-depleting substances, as measured in ODP-units, and
  - the share of waste from end-of-life vehicles and tyres.

Following the German Federal Environment Agency (UBA 1999), the diverse impacts can be grouped under three overarching objectives: Protection of human health, protection of structure and function of ecosystems, protection of resources. These objectives will be taken up for the final assessment. Full details on the data and selection are given in Borken (2005).

Impact category associated TERM indicators	**Aggrega-tion factor**	**Specif. contrib.**	**Reference year, comment, source**
Climate change			
Emissions greenhouse gases	**CO_2-eq**	**21%**	2001: excl. internat. bunkers, EEA 2003a:37.
Health protection: Air pollution			
pot. concentration of particles (PFP)	**PM_{10}-eq**	**38%**	1999: tentative aggregation of particle precursors, EEA 2003:69; de Leeuw 2002.
pot. concentration of ozone (TOFP)	NMHC-eq	53%	1999: tentative aggregation of ozone precursors, EEA 2003:69; de Leeuw 2002.
Health protection: Noise			
Exposition to traffic noise	dB(A)	-/-	no European data provided.
Annoyance by traffic noise	**#**	**50%**	lower estimate based on (UBA 2001:321) for Germany
Health protection: Accidents			
Traffic fatalities	**#, YOLL**	**40%**	Share of all accident fatalities: 30-40%. Share of all years of life lost by accident: >50%, KUSS 2002:40.
Injured	#, treatment days	15%	Share of all accident hospital admissions: 10-20%. Share of hospital treatment days of all accidents: 10-20% KUSS 2002:40.
Protection of biodiversity (terrestr.)			
Unfragmented areas *	**%**	**50%**	Assumption: Fragmentation caused equally by traffic infrastructure and settlement area.
pot. concentration of eutrophying compounds	N-pot	34%	1999: tentative aggregation, EEA 2003:69; de Leeuw 2002.
pot. concentration of acidifying com-pounds	H+-eq	25%	1999: tentative aggregation, EEA 2003:69; de Leeuw 2002.
Protection of biodiversity (marin)			
Discharge of oil at sea	t oil	22%	In long-term average about 45.000 t oil are released annually, of which ~10.000 t in accidents und ~20.000 t from illegal discharges, Pavlakis et al. 2001:6f; REM-PEC:16, 19; EEA 2002a:98.
Discovered oil discharges	t oil	44%	
Energy resources			
Final energy consumption	**mio toe**	**32%**	2001: excl. internat. bunkers, EuroStat 2001:11. Share of primary energy lower.
End-of-life vehicles and tyres	mio toe	6%	max. 6% of transport's final energy consumption, Borken 2005:90f.
Land as resource			
Land take by transport infrastruc-ture *	**%**	**ca. 40%**	Traffics share of total traffic and settlement area in D, UBA 2001.
Disposal of end-of-life vehicles and of tyres	%	<2%	max. 1% and 0,6% of total waste disposal, banned from 2006; Borken 2005:90f.
Stratospheric ozone depletion			
Emission of ozone depleting sub-stances	ODP-eq	<5%	2001: EEA 2003 02; EEA 2002a.
Abbreviations: PFP: Particle forming potential; TOFP: Total ozone forming potential; YOLL: Years of life lost. ODP: Ozone depletion potential.			

Table 1: Qualification of TERM's environmental indicators and proposal of non-redundant, pertinent and relevant key indicators (in bold) for road transport assess-ment (Borken 2005).
*: The original indicators on fragmentation and land take by transport infrastructure

are hardly sensitive to change. Therefore they are replaced by their rate of change, which also reduces systematic data uncertainties, and their values are decreasing when less infrastructure is built.

2 SYSTEMATIC EVALUATION OF INDICATORS WITH ELECTRE III

2.1 Characteristics of the ordinal, multi-criteria decision aid method ELECTRE III

Any assessment method must take into account the need to decide while the planning is pending, hence without precision, detail and reliable data. Indeed, already the selection of the representative impacts and indicators must anticipate their use in an evaluation method.

We propose for the strategic phase on an assessment a fuzzy evaluation method, that is particularly well suited to a poor data situation. We analyse here to what extent the so-called ELECTRE III method can help with strategic environmental assessment. The following characteristics appear particularly promising in our context:

- It is designed to handle imprecise data and can also use qualitative input;
- the data can be used in their natural units without any need for conversion;
- compensation can be excluded and a maximal compromise is identified instead;
- it provides a hierarchy of the cases compared, if there is sufficient ground.

ELECTRE is a good example of an important school of Multi-Criteria Decision Aid methods and has been presented elsewhere in detail (Roy & Bouyssou 1993; Roy & Vanderpooten 1996; Borken 2005). We just highlight the following fundamental assumptions:

- A case A is preferred against a case B, if and only if two conditions are satisfied:
  - There are sufficiently strong arguments to favour A instead of B, and
  - there is no significant opposition nor veto against the preference of A over B.

  I.e. neither a maximisation of advantages nor a minimisation of disadvantages are sufficient to decide between two cases. ELECTRE III is compromise-oriented and highlights strong minority votes.
- The preferences between the cases under consideration are constructed in pairwise comparisons. I.e. it is assumed, that the preferences do not exist independently of the elaboration of the problem and hence cannot simply be revealed, but that they evolve dependent on context, actors and their system's understanding.
- The assessment is ordinal: Only the differences between two indicators with respect to thresholds are important. Once these thresholds have been passed, neither its absolute value nor a potential improvement or deterioration of this indicator are taken into account.

2.2 Application of ELECTRE III to the key indicators

The representative indicators identified above continue to serve as test case. The assessment result is – with ELECTRE - independent of the specific choice of the indicator representing the impact category. Other indicators with proportionally about the same development would return the same results, as only relative developments of the different indicators and not their absolute values are taken into account. The weights are directly allocated to the impact category; they are independent of the indicator, its value or measurement unit (scale invariance). They must be provided explicitly as external input e.g. by the decision maker, the stakeholders, an assessment body. Here we analyse different weighting profiles.

Data on the environmental performance of European road transport between 1990 and 2000 is taken from the latest TERM fact sheets, for 2005 and 2010 from Samaras et al. (2002) for energy consumption, greenhouse gas and pollutant emissions, for the other indicators as trend extrapolations (Borken 2005). The different years are ranked with respect to the overall environmental performance of road transport, as measured by the TERM indicators to answer the basic question: “Is the environmental performance of transport improving?”

2.3 Elimination of uncertainties

TERM has been developed by the European Environment Agency in cooperation with EuroStat and several dedicated European Topic Centres since 1998. However the Agency considers the comparability of many data over time and space as poor. Hence it is imperative to use an assessment method that systematically accounts for these uncertainties. ELECTRE III captures them by a fuzzy treatment of the data.

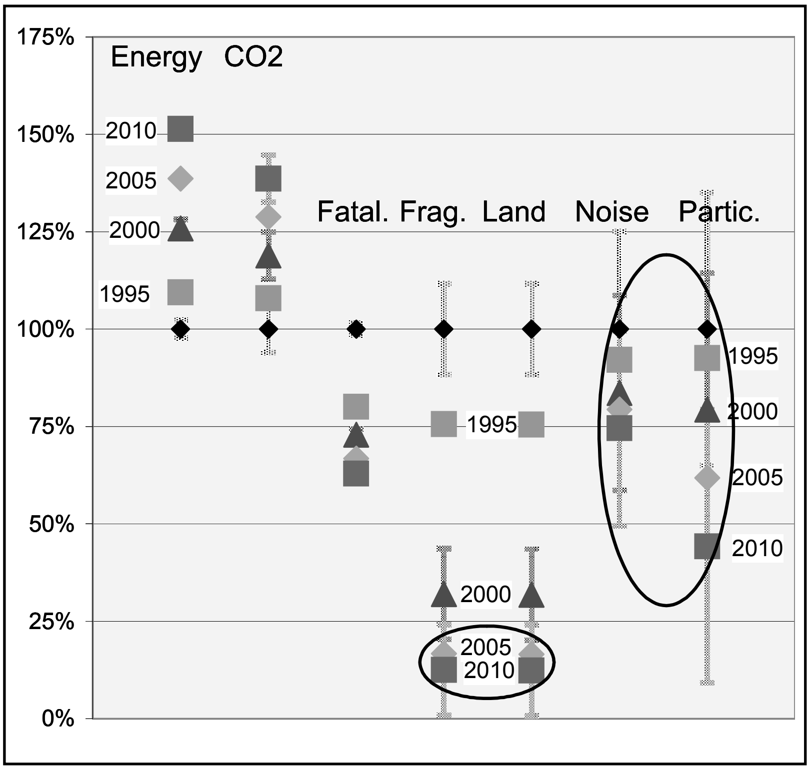


Figure 1: Data and uncertainty for the key indicators relative to 1990 (=100%). Uncertainty ranges are only given for 1990, 2000 and 2010 only, for graphical clarity.
Note: The indicators for fragmentation and land take refer to the rate of change of the construction of extra-urban transport infrastructure, which is assumed decreasing.

For the key indicators chosen from TERM, the data structure is relatively simple (Figure 1): The indicators 'transport's final energy consumption' and 'CO_2-emissions' increase monotonously, and thus become worse, while all other indicators decrease monotonously, and thus become better. However, the uncertainty for noise exposure data or, likewise, for noise perception and for air pollutant emissions - here for emissions of particulate precursors - is significantly larger than their rate of change even over ten years. Therefore these two impacts are too uncertain to discriminate transport's performance over time.

The assessment will in consequence depend on how the deterioration in the impact categories energy resources and climate change is judged compared to the ameliorations for accidents, biodiversity and land resources. As the number of indicators, and thus also data demands and handling, is reduced significantly, it becomes straightforward to identify this conflict of objectives by inspection.

2.4 Compromise identification for diverging values

Trading-off heterogeneous and opposing impacts is the essential valuation phase of the assessment. It is inherently subjective and usually gives rise to a lot of contentious, sometimes ideological debate: Different actors have different interests in transport plans, programmes and policies, and hence they attach different values to the same impact. This potentially conflicting diversity needs to be taken into account for an overall assessment. Assessment schemes inspired from economic analysis usually assume that all impacts can be converted to and manipulated on a common e.g. monetary scale: Thus they suppose compensation between different impacts, that quantitative intervals are really meaningful and constant throughout the whole range. Weights are actually conversion factors between different impacts and often elicited in a sophisticated manner.

This paper emulates different values by defining four profiles, which attach different weight to the three overall objectives, protection of health, of ecosystems or of resources. Either, all objectives receive equal weight or, alternatively, one of the objectives is given a dominant weight (50%) and the other two objectives receive the remaining 25% each. The weights refer to the impact category, therefore they are independent of the representing indicator, no conversion between indicator is implied, they refer only to dominance between two alternatives compared, and no technical procedure is needed to derive the weights. As the procedure is ordinal abstraction is made from the absolute indicator value.

These different assessment schemes allow to identify both, controversial as well as converging results in the face of individual different values. This is the starting point to identify win-win strategies. In the case of the TERM data with their simple monotonous structure, the rankings are strongly converging (Figure 2): Broadly, the overall environmental impact does decrease from 1990 to 2010 but the change between 1995 and 2000 is not clearly discriminatory. I.e. a large number of actors with different priorities can agree to accept these improvements. They are clear enough that they do not depend on the details of the assessment.

However, the environmental state between five consecutive years cannot reliably be discriminated. This reflects on the one hand the inertia of the transport system, on the other hand however also imprecise data and insensitive indicators. These need therefore be redefined in order to serve as a finer and more reliable instrument for analysis and assessment. A first step has already been undertaken here: As the indicators for land use and fragmentation are hardly sensitive over 10 years time, we propose here to use their rate of change. Thereby, these indicators are not only more sensitive but also systematic imprecision cancels out.

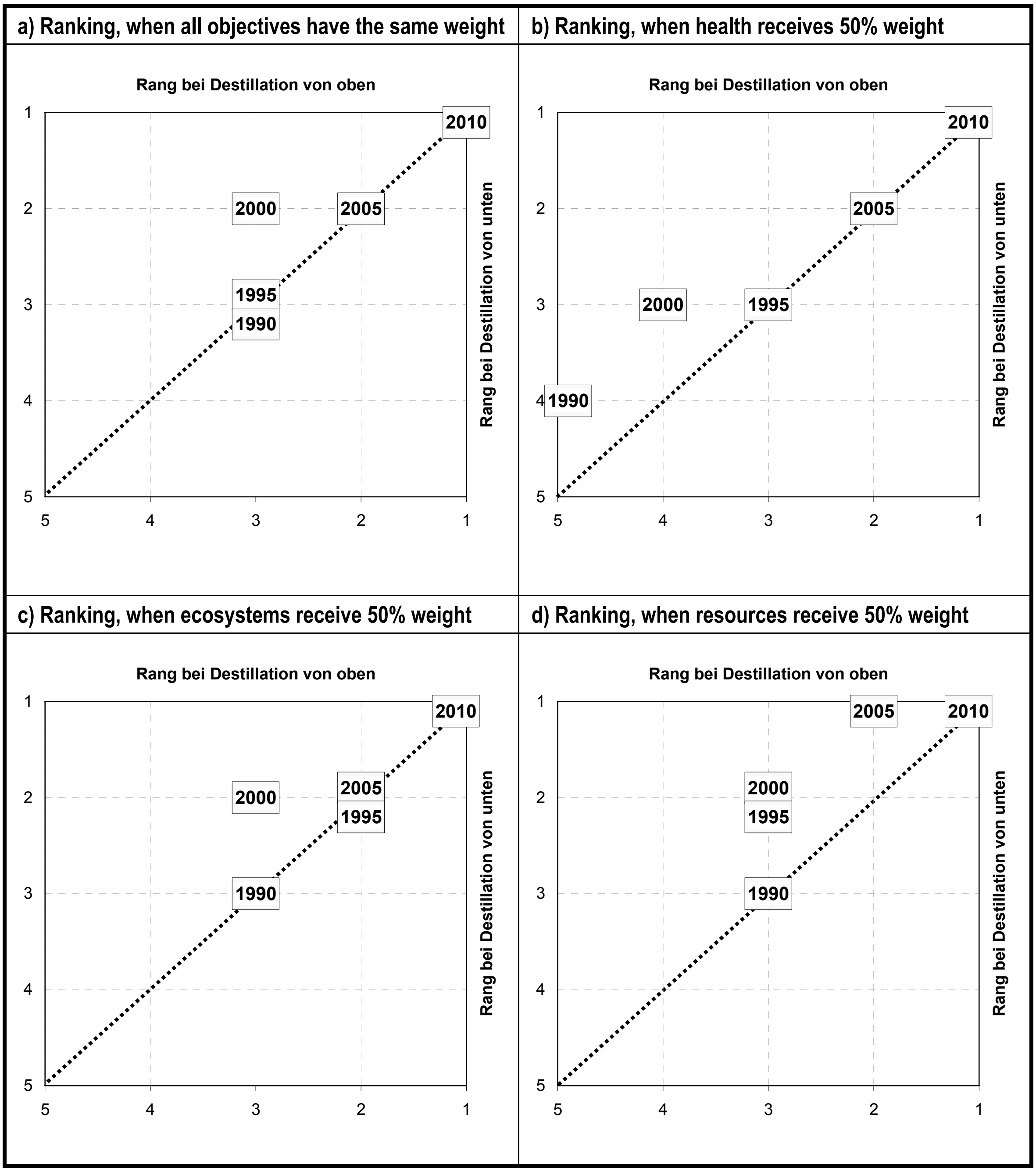


Figure 2: Ranking of Europe's road transport's environmental impact over time – as measured by TERM indicators – as a function of different weighting profiles a)-d). Read: The rank from the top is given on the horizontal axis, the rank from the bottom on the vertical axis. When both coincide the ranking is unambiguous and the year is represented at the diagonal. Deviations from the diagonal indicate ambiguities in the assessment. The more towards the upper right corner, the better the overall rank.

2.5 Return the dominant assessment?

Where are the limits of the common assessment? As there are only two impact categories, represented by the indicators energy consumption and CO_2-emissions, whose performance deteriorates over time, a rank reversal can only occur, when their relative weight is increased (Figure 3). A simple iteration reveals, that as soon as 40% of the overall weight are allocated to these impact categories, the various years can no longer be discriminated: Advantages and disadvantages in the overall environmental performance of

Europe’s road transport balance each other and their changes are not decisive. As soon as 60% of the overall weight is allocated to these impact categories, their performance determines an overall negative assessment. Given an ordinal assessment logic, where the absolute development of the indicators does not influence the weight, i.e. the relative importance of the impact categories, only a very strong weighting up to a veto can change the ranking.

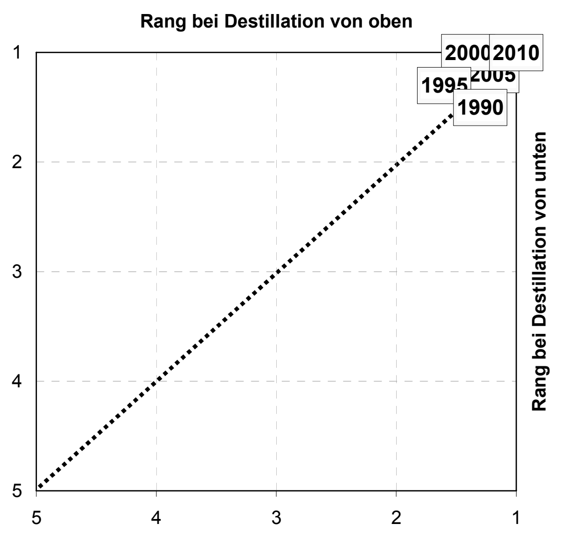
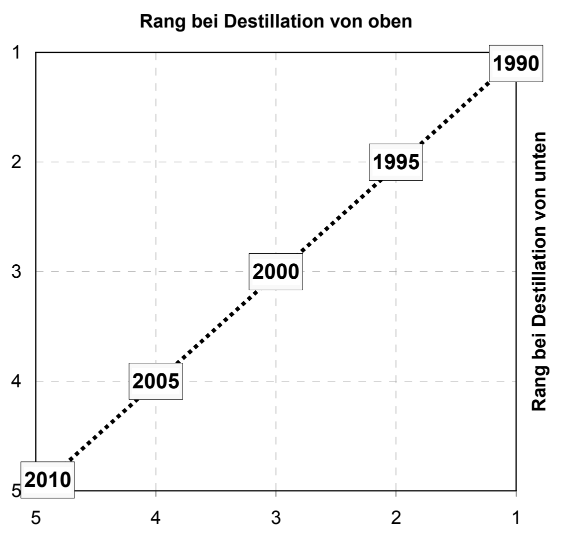
a) Ranking, when CO_2 and energy consumption have 40% weight	b) Ranking, when CO_2 and energy consumption have 60% weight
	

Figure 3: Sensitivity analysis: No ranking is possible when the impact categories energy consumption and climate change receive 40% of the total weight (a), when they receive 60% or more (b), the environmental impact from Europe’s road transport is judged to deteriorate with time (rank inversion).

A systematic sensitivity analysis of the technical parameters of the assessment method - the indifference and significance thresholds, the distillation degree – excludes any significant influence (Borken 2005): The variation of these parameters influences the resolution between the different years but not their ranking. Hence, the monotonous performance of the indicators not the method determines this result.

2.6 Key results: Infrastructure expansion and fuel consumption decisive

The impact categories noise and air pollution do not play an important role in the assessment as their uncertainty is too large. The impact category ‘accidents’ can rely on highly precise fatalities data. But on its own this indicator will rarely receive enough weight to *decide* an assessment, unless they block an outranking by a veto. The remaining reliable indicators are not independent: The indicators ‘final energy consumption’ and ‘CO_2-emissions’ can be referred to the fossil fuel consumption and, likewise, ‘land use’ and ‘fragmentation’ can both be referred to the length of the extra-urban traffic infrastructure. In consequence their weight is always allocated in pairs and thus has decisive power. As a matter of fact, the multi-criteria problem can – for road traffics' impacts – be focused on two key parameters, the fossil fuel consumption on the one hand and the extra-urban infrastructure construction on the other hand!

Assuming continued reductions of traffic noise and pollutant emissions, the environmental performance of road transport in Europe can be further improved, if the fuel consumption is reduced and as much as possible decoupled from CO_2-emission; furthermore, extra-urban infrastructure construction should be kept minimal and decoupled from fragmentation.

3 SUMMARY AND LESSONS

This paper has systematically reviewed two central questions for environmental impact assessment: What are the relevant environmental impacts of transport? Are they improving, i.e. how can they be assessed? To be as useful for real decision making as possible we have focussed on the transport and environment indicators TERM of the European Environment Agency, in operation since 1999.

The systematic review of the TERM indicators broadly confirms their general suitability. However, we have identified numerous points for improvement:

- A classification according to environmental impact categories would increase overview.
- Numerous indicators do not appear representative for transport as a source, nor pertinent for an environmental impact. Either these indicators should be dropped or their cause-effect chains must be presented.
- For some of the pertinent indicators transport's contribution to the environmental impact seems small.

These criteria allow to streamline the current twenty-four indicators to a maximum number of seven key indicators without lack of relevant information. Their focus is strongly increased data demand is reduced by a factor of three. We propose to consider these key indicators for any strategic environmental assessment where overview and not detail is needed.

In a second step these key indicators are submitted to an overall assessment for the first time. Methodologically sound arguments are presented to decide on an overall improvement of transport's environmental performance. Using the ordinal multi-criteria assessment method ELECTRE III we have identified a broad range of individual weights, that allow to ascertain that the environmental performance improves from 1990 to 2010 in the old European Union (EU15). Further lessons can be drawn from this assessment:

- TERM does only present comprehensive data for road transport. It should therefore be expanded to the other transport modes to live up to its own aspirations.
- Data uncertainties significantly hamper the interpretation of air pollution and noise indicators. Unless these data are improved, all investments in data collection are in vain.
- Land take and fragmentation are crucial indicators but hardly sensitive over time. We propose to replace the absolute values by their rate of

change to make them more sensitive and also to reduce systematic data uncertainties.

- Objectives for a good environmental performance are needed to decide whether a better performance is sufficiently good.

Often it is argued that judgements are the job and privilege of politicians and society. The method provided here allows to identify agreement for a wide range of diverging judgements. We propose to consider its application in the first phases of a Strategic Environmental Assessment, when different interests and heterogeneous input need to be screened. Independent of individual values the analysis presented provides arguments to design win-win strategies for transport's environmental improvement. Efforts should focus on a reduction of fuel consumption and its decoupling from CO_2-emission; moreover, extra-urban infrastructure construction should be kept minimal and decoupled from fragmentation if the environmental performance of road transport in Europe shall be improved further.

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Keys-words:

Impact assessment, TERM, multi-criteria, ELECTRE, compensation, environmental indicator

Conference theme:

European Policy and Research, Project Appraisal, Session EPR 03ii

Word count: **4362**