Incorporating Sustainable Development into Transport Infrastructure Assessment inside Urban Areas

Abstract PhD-Thesis

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1 Introduction

Every country in the world would like to enhance its' standard of living. At least since the final report of the World Commission on Environment and Development in 1987, many countries now consider that further improvements in standards of living should happen in a sustainable way.

The transportation system provides people access to economic activities, to their surrounding communities, and to the purchase of goods and services[1]. Therefore, the characteristics of any given transportation system have an enormous impact on people's daily lives. The quality of access provided by such a transportation system for example affects people's travel behaviour. Negative impact, such as pollution and noise, can significantly reduce the peoples' quality of life. For this reason, transport systems should support the concept of sustainable development.

Consequentially, it should be possible to assess whether a proposed transport infrastructure supports the concept of sustainable development. Right now, no assessment methods exist to evaluate this question. The design of one method as a possible approach is the objective of this PhD-Thesis.

The effects caused by transport infrastructure depend on the kind of transport infrastructure itself and on the environment in which the transport infrastructure finds itself. It appears careless to evenly apply exactly the same assessment method for various, different kinds of transport infrastructure. Rather, it is important to adjust the assessment method to the specific circumstances of the various kinds of transport infrastructure.

In this paper, an assessment method is developed for assessing transport infrastructure located within urban areas. It is possible to use this method if the task of the assessment is limited to evaluating a few different plans for one proposed transport infrastructure (a "hot spot"); i.e. the assessment method applies when:

– Someone wants to include aspects of sustainability in their evaluation method;

[1] OECD Proceedings; Towards Sustainable Transportation, The Vancouver Conference; Paris, 1997. P. 62

– There are a limited number of different plans for one proposed transport infrastructure; and
– The transport infrastructure being evaluated is located within an urban area.

This paper is divided into four chapters:

The task of Chapter 1 is to operationalize the term “sustainable development” with the objective being to develop a suitable definition and a general, workable approach for measuring sustainable development. Chapter 2 discusses which effects should be included in an assessment method for assessing transport infrastructure located within an urban area. Furthermore, it will also discuss which indicators are suitable for measuring the selected effects. Chapter 3 deals with the structure of the assessment process. And Chapter 4 explains the decision making process for selecting the most appropriate plan.

2 Operationalization of Sustainable Development

Today, the Brundtland-Definition of "sustainable development" is widely used. Therefore, it will be considered the basic operating definition for this paper. The Brundtland-Commission defines sustainable development thus:

> *Sustainable development, is a development that meets present needs without compromising the ability of future generations to meet their own needs. Sustainable development should include economical, ecological and social aspects.*

Because it is impossible to develop exact guidelines from such a general definition, it is very difficult, indeed, to use this definition directly as an assessment method for evaluating any given traffic infrastructure. For this reason, it is necessary to encircle the definition. This is achieved by applying the concept of "critical sustainability," which has its roots in Ecological Economics[2]. This field of science addresses the interconnections between the ecological and economic systems, with special focus on workable methods for measuring and quantifying "sustainable development."

When applying this approach, sustainable development is determined by measuring the economic value of the entire earth's capital stock. Sustainable development is warranted, if, when applied, the economic value does not decline over time.

The capital stock can be classified further into either natural or man-made capital stock. Natural capital stock includes all natural resources, for example, crude oil, coal, groundwater, animals, trees, as well as, all natural cycles, such as hydrologic cycles, food chains, all life support systems, etc. Man-made capital stock includes the total sum of all goods and products produced by mankind. This would include simple bridges, all products, as well as, knowledge and the value of social structures).

The value of capital stock does not mean solely the economic value of specific natural resources or man-made products (e.g. the value of a barrel of crude oil or the value of a bridge or building), but, includes also in its meaning economic value,

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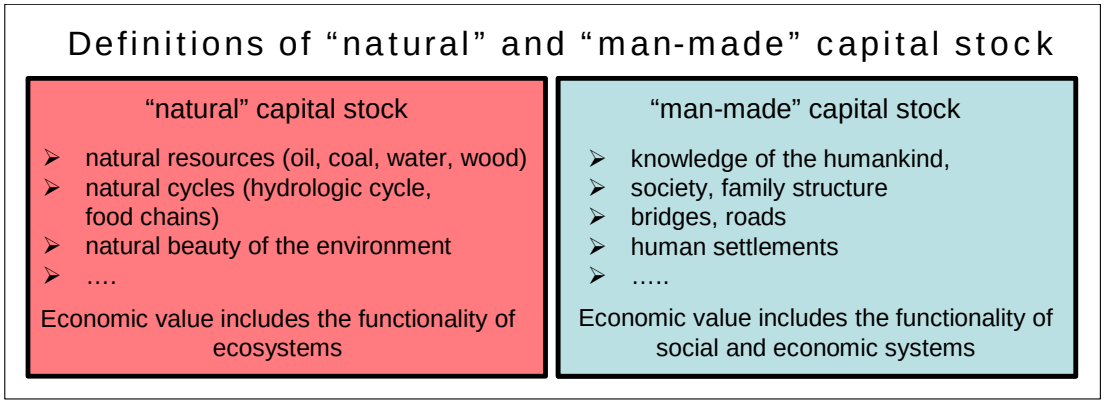
[2] For further information see, e.g.: Daly, H.; Beyond Growth: The Economics of Sustainable Development, Boston 1996.

in terms of global ecosystem "functionality," the value of inherent natural beauty of the environment, the value of a society or a family, etc. This principle is emphasized in the following figure:



Three distinct main theories of sustainable development can be derived from the concept of the constant value of the capital stock[3]. These are the "strong," "weak" and "critical" sustainability theories. The main distinction between the different theories is on whether substitution processes between natural and human made capital should be permitted or not. We must ask: is it possible to reduce the value of one part if the value of another part is increasing at the same time in such a way that the value of both parts don't decrease?

Critical sustainability admits for consumption and, therefore, the reduction in natural capital[4]. However, the reduction process of the natural capital is limited. Reduction in natural capital stock is only possible:

1. when the natural life cycles and life supporting systems, which support these natural resources, are not destroyed or adversely affected by the consumption; and

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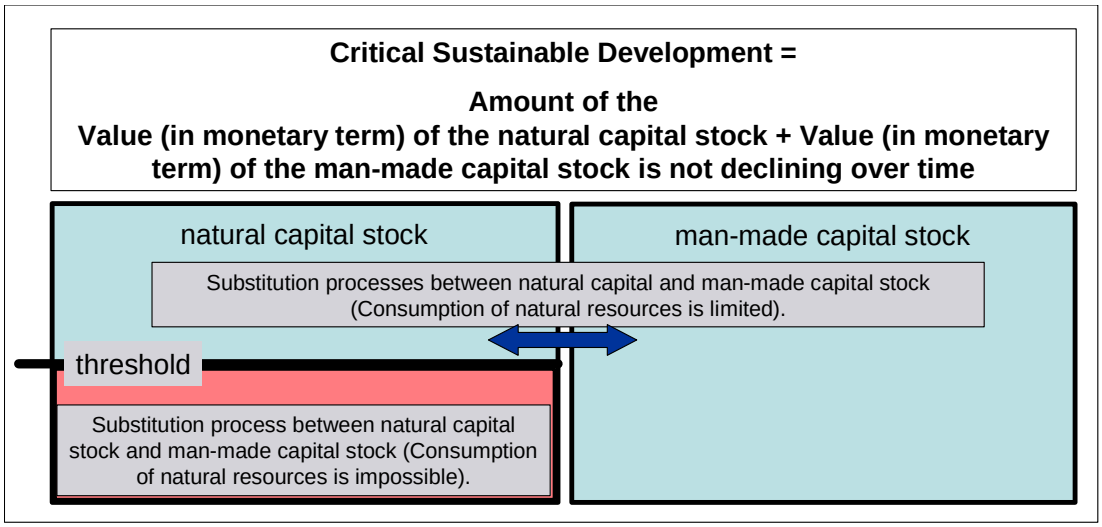
[3] Each of these concepts can be divided into further sub-concepts. For further information see, e.g.: Pearce, D.; et. al.; Sustainable Development; Economics and Development in the Third World; Blueprint for a Green Economy. London, 1990.

[4] The concept of strong sustainability fails to allow any substitution processes between natural and human made capital. This means the value of both parts may not decrease over time. Consequently, it is impossible to use any of the natural capital stock for consumption. The concept of weak sustainability allows for, in opposition to strong sustainability, unlimited substitution processes between natural and man-made capital. Therefore, it is possible to deplete the natural capital stock without any restrictions, as long as, the value of the man-made capital increases by the same amount as the value of the natural capital stock decreases. Considering these facts, then, strong sustainability and weak sustainability are both theoretical concepts, but whose requirements cannot be fulfilled in reality.

2. as long as the reduction in the value of the natural capital stock is compensated by an equal increase in the value of the man-made capital stock.

These characteristics are shown in the following figure.



These requirements can, theoretically, be fulfilled. Therefore, the concept of critical sustainability is not in opposition to conditions in reality. However, the critical factor is in the answer to the following questions: how much of each individual part of the natural capital stock can be used for consumption? And, does the consumption process of natural capital lead to a sufficient increase in the value of man-made capital stock.

It is quite unlikely that a minimum value amount of each natural resource can be determined, largely due to the huge complexity of interactions inside the global ecosystem. It would be necessary to understand the complete functionality of all natural life cycles and life supporting systems to identify the minimum value amount of each specific natural resource. This demand appears unrealistic.

It is also impossible to measure increase in the value of man-made capital stock, as well, since there no appropriate methods exist for measuring the total value of man-made capital stock, for example, a suitable method for measuring the economic value of a given society, etc). Therefore, critical sustainability is a concept which corresponds with reality. However, it is impossible to conclude whether or not the concept of critical sustainability has been fulfilled.

If the improvement of sustainable development is an objective of any given society, then it must be possible to formulate some strategies on how that society could meet this objective. There is not only a need for guidelines, but also methods for measuring and monitoring sustainable development. Therefore, it is necessary, both to simplify the concept and to accept some uncertainties. Otherwise it is impossible to develop working guidelines and methods for measuring and monitoring sustainable development. One possible way of simplifying the concept is the subject of the next chapter.

2.1 Simplifying the Concept of Critical Sustainability - Minimal Requirements Necessary for the Process of Sustainable Development

As mentioned above, it is impossible to check whether transport infrastructure meets the demands of critical sustainability. The problem is found in the difficulty of determining the economic value of various categories of natural and man-made capital stock (e.g. the value of a given society, or the value of the inherent natural beauty of the environment). For this reason, it is impossible to use the total economic value of the capital stock as an indicator for measuring sustainable development. However it has been determined that development is definitely unsustainable if the amount of natural capital stock is less than the critical amount which is necessary for preventing infringement on the natural processes which are based on this natural capital. Therefore, it is impossible to determine whether a development is sustainable, or not, but it is possible to identify the conditions of "unsustainable" development. Therefore, one method for determining "unsustainable" development could be to prove whether or not the total value of the natural capital stock has fallen below the critical level.

The inherent problem of this approach is that it is impossible to calculate even the minimal amount of any given natural capital stock. For dealing with this problem, Pearce[5] recommends a simple solution. He claims: As long as it is not possible to determine the necessary minimal amount of each natural resource, a risk avoiding strategy should be followed. Therefore, the current amount of any natural capital stock to be evaluated must be the critical amount. This strategy complies with the

[5] Pearce, D.; et. al.; Sustainable Development; Economics and Development in the Third World; Blueprint for a Green Economy. London, 1990. P 8.

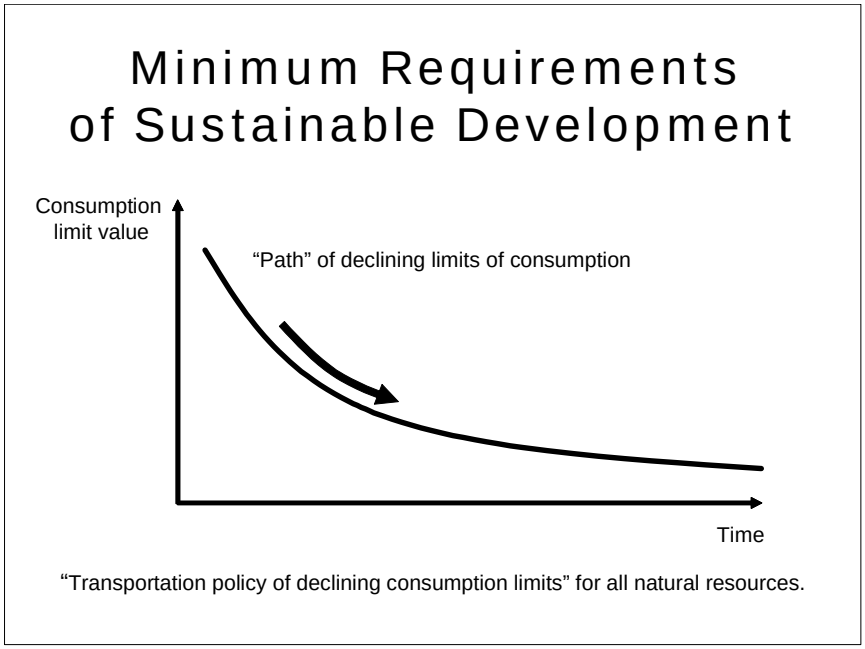
demands of strong sustainability since it doesn't permit the use of any part of the natural capital stock for consumption. Literally, no consumption of natural capital stock means, among other things, stopping all economic activities and, therefore, all kinds of traffic, as well. This demand can not be the objective of the assessment method. The only realistic and applicable objective of the transport system can be to reduce the consumption of the natural capital stock over time. For meeting this objective, it is essential:

1. to implement consumption limit values (threshold) for each part of the natural capital stock; and

2. that these consumption limit values (threshold) can not remain stable, but, rather, must decline over time since the critical amount of each part of the natural capital stock is unknown.

If a given transportation policy follows a path of declining consumption limits over time, then it is still impossible to determine whether the transport system conforms to the concept of sustainable development. It is possible to say, however, that any development of transport systems would be moving toward sustainable development.

Therefore, these declining consumption limit values of natural capital stock over time are a minimum requirement for sustainable development. This concept is shown in the following figure:



This minimum requirement can not be used to prove whether the development of a given transport system is sustainable. If these minimum requirements are not fulfilled, however, then it is, by definition, unsustainable development. There are several consequences if this approach is used:

1. It would be necessary to implement a policy to govern the declining consumption limit values over time. The assessment method of the transport infrastructure must include checking whether the transport infrastructure complies with this policy. For this purpose, the assessment method must audit whether the transport infrastructure is meeting the valid consumption limits of the natural capital stock.

2. Natural capital stock is more important then man-made capital stock. This claim is possible the economic and social systems are included as parts of the ecological system. The ecological system can exist without human-based economic or social systems. However, the converse is not equally possible, due to the fact that both economic and social systems can not exist without the ecological systems.

3. It is impossible to determine the level of sustainability of any given transport infrastructure. Rather, it is possible to determine only whether a proposed infrastructure supports the concept of sustainable development.

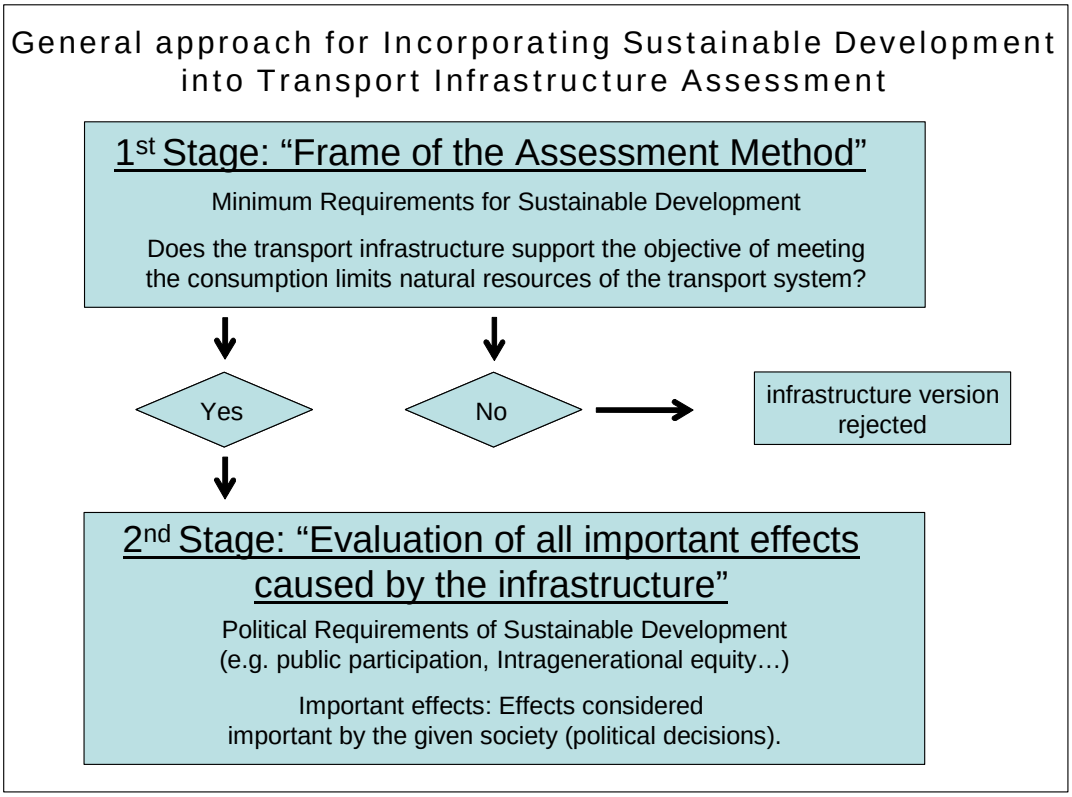
These minimum requirements can be used as a basement in developing an assessment method.

2.2 General Approach for Incorporating Sustainable Development into Transport Infrastructure Assessment

According to the affiliated concept of minimum requirements for sustainable development, the assessment method must test whether the consumption limit of the natural resources' values are not infringed upon by the transport infrastructure. As a result, all infrastructure plans which consume more natural resources than permitted should be rejected because these plans do not support the concept of sustainable development.

This concept appears to provide a possible approach. However, these minimum requirements on sustainable development are not sufficient, by themselves, for an assessment method of traffic infrastructure. There are also serious effects, which may not be important with respect to the impact on natural capital stock, but very important for the living conditions of the people who live adjacent to the transport infrastructure. These effects, of course, can not be ignored. Therefore, there is a need for further evaluation. This evaluation follows the elimination of all plans which do not fulfil the minimum requirements on sustainable development.

All impact on the transport infrastructure not closely related to the depletion of natural resources, but still considered as important of transport infrastructure will be included in the second part of the assessment. Important effects are those effects which are considered as important within any given society. These can be political guidelines which come bundled together with the concept of sustainable development (e.g. public participation) and/or effects which characterise the traffic infrastructure itself (e. g. level of accessibility for the people). Therefore, the general approach for incorporating sustainable development into the assessment method has two stages. This two-stage process is shown directly below:



It is now necessary to select the effects which should be included in the first and second stage of the assessment method. There is also a need to define some

requirements of the evaluation process itself. (What are the given demands on an evaluation process with respect to sustainability? (Political requirements.) These effects are selected in the next chapter.

3 Selection of Effects of Transport Infrastructure and Indicators for the Assessment Method

The first objective of this Chapter is to develop a list of the various ways transport infrastructure impacts on its environment to be integrated into the transport infrastructure assessment method. A further objective is to search for the requirements on the structure and characteristics of an assessment method with respect to sustainable development. These requirements will be used as a basis for specifying the general approach for incorporating sustainable development into the transport infrastructure assessment method in Chapter one.

As mentioned in Chapter 2, this assessment method will be designed for transport infrastructure in urban areas. Therefore, the selected effects are only suitable for this type of infrastructure. It is impossible to use them for assessing any other infrastructure without any adjustments.

It is theoretically possible to come up with an unlimited number of effects on the transport infrastructure and demands on the characteristics of the evaluation process. An unlimited number of effects, of course, cannot be included into this assessment method. For this reason, it is necessary to include only important and concise effects. The problem in this connection is that there is no one perfect definition of what exactly are concise effects on a sustainable transport infrastructure which supports the concept of sustainable development, since these effects always depend on the moral concepts of any given society and on the specific physical characteristics of that transport system. Thus, the selection is affected by normative decisions which must be carried out by the society. For this reason, effects considered concise by one society are not always those of another society; every society varying from region to region.

This paper provides a proposal based on primary research. The objective of the research was to determine what effects are currently considered important by a given society in respect to effects on transport infrastructure and the assessment

process. Therefore, the selected effects are only suitable for the current transportation system in Germany. So they are not applicable without some adaptation, in a different region or country.

Resolutions and political guidelines on sustainable development like the

– Rio Declaration on Environment and Development (Agenda 21)[6];
– OECD Proceedings; Towards Sustainable Transportation[7]; and
– European Conference of Ministers of Transport; Assessment & Decision Making for Sustainable Transport[8], etc.

are used in this research. The research results are finalised in a list of demands on an assessment process for transport infrastructure in regard to sustainable development. Aside from general requirements on evaluation methods which are valid for every type of assessment , for example:[9]

– A high level of transparency in the assessment methods;
– Reliability;
– Simplicity;
– Reduced complexity; and
– Conciseness

Requirements exist which are not currently always part of the assessment process of transport infrastructure. These include:

– An integrated assessment of economic, environmental, health and social aspects;

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6 http://www.unep.org/Documents/Default.asp?DocumentID=52

7 OECD Proceedings; Towards Sustainable Transportation, The Vancouver Conference; Paris, 1997.

8 European Conference of Ministers of Transport; Assessment & Decision Making for Sustainable Transport; Paris 2004. P 232.

9 See, e.g.: Beckmann, K.; Bewertungsverfahren weiter auf dem bisherigen Weg? Erfordernisse eines Methoden Mix; Institut für Stadtbauwesen an der RWTH Aachen P. 39;
Hauger G.; Grundlagen der Verkehrsökologie; Österreichischer Kunst- und Kulturverlag; Wien 2003, P. 38,
Scholles, F.; Institut für Landesplanung und Raumforschung der Universität Hannover, Skript zur Vorlesung Gesellschaftswissenschaftliche Grundlagen, Planungsmethoden, 7.9 Grundfragen der Bewertung; im Internet unter: http://www.laum.uni-hannover.de/ilr/lehre/Ptm/Ptm_Bewertung.htm

– An comprehensive evaluation of all modes of transport;
– A method for highlighting trade-offs without the assessment, making judgments, instead of the decision maker; and
– Stake holder involvement and general public participation.

These requirements above are included in the design of the assessment method in Chapter 4.

The second result of the literature research is a compilation of concise physical characteristics of the stated transport system, which should be integrated into the transport infrastructure assessment method. As a next step, it was necessary to select indicators for measuring these characteristics of the transport system. The selection of the indicators is based on primary research, as well. Research papers from the Program "Transport and Environment" of the National Research Program of Switzerland (NFP41)[10], the German Federal Ministry of Transport, Building and Housing[11], the OECD (Organisation for Economic Co-operation and Development) Research Program "Environmentally Sustainable Transport"[12] were used in the selection of the indicators. A summary of the selected effects and indicators are shown in the following table.

[10] Ernst, Basler & Partner Ltd ; Measuring the Sustainability of Transport, Project C5; Transport and Environment; Interactions Switzerland/Europe National Research Programme 41 Bern 1998.
[11] Federal Ministry of Transport Building and Housing; Federal Transport Infrastructure Plan 2003; Berlin 2003.
[12] OCDE; Environmental Criteria for Sustainable Transport, Report on Phase 1 of the Project on Environmentally Sustainable Transport (EST); OECD - Environment Directorate, Paris 1996.

EFFECT	INDICATORS
Accessibility	Accessibility to points of interest (all traffic modes)
Traffic Safety	Number of traffic accidents
Air Pollution (with regard to exposed people, animals, plants, buildings)	Nitrogen oxides, Volatile organic compounds, Benzene, Particular matter
Global Warming	Carbon dioxide
Noise (with regard to exposed people)	Noise
Consumption of natural resources	Carbon dioxide (as an indicator for the consumption of crude oil) Land Use
Effects on urban environment	Effects on the amenity value of the adjacent areas Effects on the urban space quality Effects on separation Effects on the quality of the urban climate
Investment cost	Investment costs
Operating costs	Operating costs
Intragenerational equity	Accessibility distinctions among homogeneous behavioral population groups
Intergenerational equity	Level of pollutants and consumption

The selected indicators are useful for the current transportation system in Germany. A transportation system at a different time (e. g. in 10 years) or in another region requires different indicators.

4 Structure of the Assessment Process

The design of the assessment method is based on the general approach for incorporating sustainable development into transport infrastructure assessment (see Chapter One). The assessment method should meet the list of requirements on an assessment process for transport infrastructure with regard to sustainable development (see chapter three). One important demand (in addition to the other requirements) on the assessment process is to engage the public into the decision making process. Therefore, the assessment method should support public participation.

The objective of public participation is that the elected politicians or stakeholders can discuss the advantages and disadvantages of each plan and select the most appropriate plan. However, engaging the public involves some risk. People may selfishly select the plan which best suits them. There is no guarantee that the selected plan is the best plan for society, as a whole[13].

As a consequence, the assessment structure must include some tools which make such self-interested decisions of the decision makers impossible. This is particularly important because the general approach for incorporating sustainable development into the transport infrastructure assessment in Chapter One requires that all plans which do not meet the minimum requirements on sustainable development, must be rejected.

Therefore, there is a need for eliminating all plans which do not fulfill these minimum requirements, prior to the public becoming involved in the decision making process. Thus, the decision maker can only select among those proposals which are, in principle, acceptable. This process of elimination must be the first stage of the assessment method.

[13] However, it is impossible not to infringe at times on the needs of some people. It will always be possible to find at least one person who is negatively affected by the infrastructure. So, the level of possible negative affects must be set by the society. These levels are limiting values. The meaning behind limiting values is that the level of negative affects on some people is acceptable and less important than the increase of benefits to the whole society. The level of acceptable negative affects is a normative decision which must be carried out by the society.

The minimum requirements on sustainable development are the consumption limits of the natural capital stock (maximal acceptable consumption of natural resources) However, aside from these minimum requirements, some principle legal requirements must be fulfilled (maximal acceptable public health risks), such as emission limit values (e. g. for pollution and noise).

Furthermore, it is possible that the institution responsible for the transport infrastructure (e. g. a municipality or state administration) has special demands placed on it (such as a certain level of effects on the amenity value of the adjacent areas). Adherence to these special demands must be verified in the first stage of the assessment process, as well.

The first stage of the assessment process is completed after all unacceptable plans have been eliminated. It is then possible to engage the public into the decision making process. This will be the second stage of the assessment.

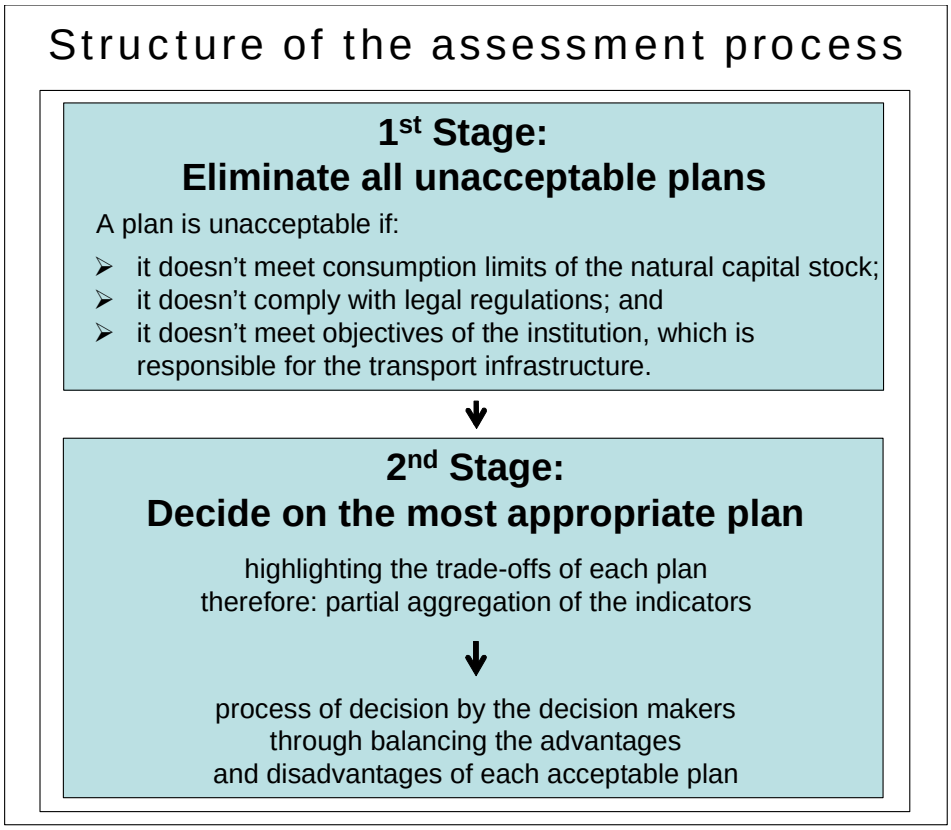
However, the question remains as to how public engagement should be organized? A fundamental requirement should be that the decision makers can clearly identify all advantages, disadvantages and trade-offs of each plan. For this reason, the amount of information to be assessed must be reduced to only the most concise characteristics of each plan. This can be accomplished by aggregating the indicators which describe characteristics of the transport infrastructure. The only remaining question is how to decide the best level of aggregation.

If all indicators are aggregated to one main indicator only, for example, the cost benefit value (economic rate of retune (ERR)) in a cost benefit analysis (CBA), then the decision making process is simplified because the information available for each transport infrastructure plan is limited. However, it is impossible with this method to discuss, weigh and balance both the advantages and disadvantages of each plan because the trade-offs are invisible, concealed behind the cost benefit value. Therefore, an aggregation to one main indicator is not appropriate for this assessment method.

Surveys have shown that people, when analyzing information in order to make informed choices, can usually balance no more than 5 to 9 different criteria. If more criteria are provided, then it becomes difficult to keep track of all possible effects. Therefore, a partial aggregation with the objective of creating between 5 and 9 main

indicators appears to be the best solution for providing a sound basis for an efficient, effective decision making process.

These considerations lead to the following figure indicating the structure of the assessment process:



It is now necessary to design a proposal on which indicators should be aggregated. This can be done through many various approaches. Therefore, this is a normative decision, as well. The approach used for this assessment method is to aggregate indicators which characterise similar effects on transport infrastructure (for example, all indicators which measure the different types of air pollution) and / or effects which can be measured in the same units of measurement (for example, investment and operating costs).

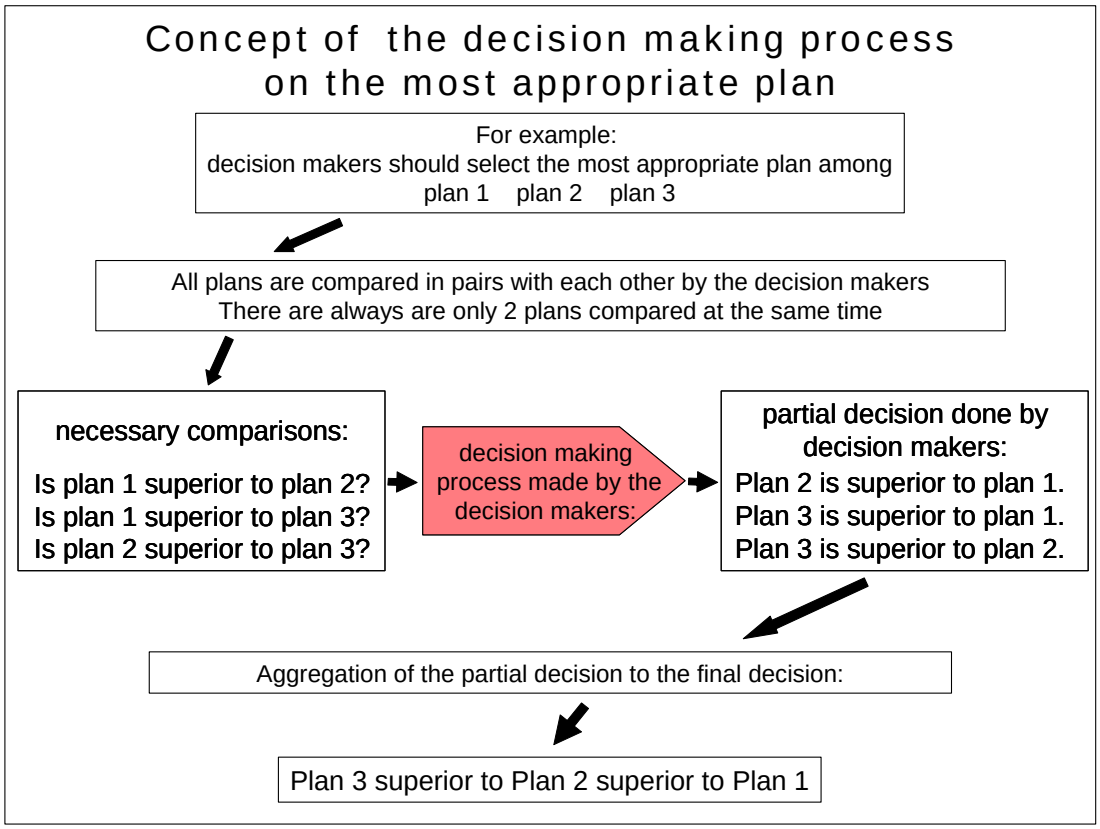
The designed aggregation proposal is shown in the following figure (The developed mathematical terms and rules for the aggregation are not shown in this abstract.):

MAIN INDICATORS	AGGREGATED (PARTIAL) INDICATORS
Accessibility	Accessibility
Cost of Accidents, Air Pollution and Noise	Traffic Safety Air Pollution Noise
Carbon dioxide (for Global Warming and consumption of crude oil)	Carbon dioxide
Land Use	Land Use
Effects on urban environment	Effects on the amenity value of the adjacent areas Effects on the urban space quality Effects on separation Effects on the quality of the urban climate
Investment and Operating costs	Investment costs Operating costs
Intragenerational equity	Accessibility distinctions among homogeneous behavioral population groups

The next objective is now to formulate the process for decision making. This will be discussed in the next chapter.

5 The Decision Making Process to Determine the most Appropriate Plan

The developed decision making process is derived from "the method of balancing and discussion"[14]. The original method is very complicated. Therefore, a simplified version was developed for this assessment method. The general concept underlying the decision making process is shown in the next figure.



The main idea is to split the decision making process into several partial decisions. The decision makers must compare and balance all plans in pairs amongst each other (They must compare never more than 2 plans, at the same time). By n plans there are n *(n-1)/2 necessary partial decisions[15].

[14] FGSV- Arbeitspapier Nr. 58; Beurteilungs- und Abwägung mit Hilfe des Formalisierten Abwagungs- und Rangordnungsverfahrens (FAR) Ausgabe 2002. Köln 2002.

[15] The sum of necessary partial decisions increases exponentially. If the decision maker must select one plan from among 3, then 3 partial decisions would be necessary. If the decision must be determined from among 4 plans, then there would be already 6 partial decisions. Therefore, this method can only be used if the selection process must be carried out among a limited number of plans.

The decision makers must always carefully consider the question: Is plan A superior to plan B? The decision makers use the main indicators for their decisions. For this reason, the main indicators will be arranged into three separate columns.

All main indicators which indicate favoring plan A over plan B are collected in the column: “Advantages”. All main indicators favoring Plan B over plan A are collected in the column: “Disadvantages.” Finally, all indicators finding plan A and plan B equal are collected in the column: “Equal”. One example of this categorization is shown in the following figure:

Involvement of the Decision maker

Questions	Advantages	Disadvantages	Equal	Decision	Reasons for the decision
Is plan 1 superior to plan 2?	**Cost of Accidents, Air Pollution and Noise** plan 1 = 8 € plan 2 = 9 € **Investment and Operating costs** plan 1 = 3 € plan 2 = 12 €	**Accessibility** plan 1 = 0,69 plan 2 = 0,73 **Effects on urban environment** plan 1 = No. 3 plan 2 = No. 2 **Intragenerational equity** plan 1 = 3 plan 2 = 2	**Carbon dioxide** plan 1 = 6 t plan 2 = 6 t **Land Use** plan 1 = 10 m^2 plan 2 = 10 m^2	Plan 2 is superior to plan 1.	XXXX

Persons not involved in the decision making process should be able to, upon review at a later time, comprehend the completed decision making process and prove whether the decision making process was valid and consistent. Hence, the decision maker must document the reasons for their decisions. This is very important because, without any documentation, it will be impossible to prove the validity and uniformity of the partial decisions at a later time.

The final decision for the most appropriate plan is based on the total sum of the partial decisions. After aggregating the partial decisions, one plan is selected as the most appropriate plan and the evaluation process is completed. The selected plan should now be approved by the responsible political institution and can be put into practice.