TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

DIPLOMARBEIT

Methods for the Evaluation of Projects to Establish Intelligent Transportation Systems

ausgeführt zum Zwecke der Erlangung des akademischen Grades eines
Diplom-Ingenieurs
unter der Leitung von

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Wien, 29. September 2010

To

My Parents

for their essential support which allowed me to reach this point.

Acknowledgements

Firstly, I would like to thank my academic advisor, Professor Schönbäck, for his guidance in the process of completing this text. The advice on structuring the text was as valuable as the critical comments with regards to its contents.

Special thanks to the Austrian Institute of Technology – Mobility Department, Business Unit: Dynamic Transportation Systems, for initially inspiring the thesis and employing me to develop it. In particular, I would like to mention Dipl.-Ing. Gudrun Maierbrugger and Dr. Irmgard Zeiler (meanwhile formerly AIT), who contributed important suggestions, especially during the first half of establishing the thesis. The many discussions and indications to relevant publications provided by other colleagues are also highly appreciated.

Finally, I would like to thank Thomas Telepak, Rena Katikos and Peter Calließ for dedicating notable amounts of their scarce time to help me with formal corrections and proof reading.

Abstract

The need for evaluation, that is the methodologically structured analysis and comparison of projects, arises from complex decision-making problems. Transportation projects often provide such challenges for decision-makers. The practice of evaluation regarding conventional transportation projects, mainly this refers to the construction of roads and other physical infrastructure, receives significant attention in both the relevant engineering disciplines and public discourse. This is not the case regarding Intelligent Transportation Systems (ITS). This thesis sets out to determine the state of the scholarly debate on the evaluation of ITS, presents a set of important evaluation methods, and analyzes three cases of ITS project evaluations conducted by experts to gain insights on the actual practice of evaluation in the area. As it is previously necessary to understand ITS projects, different aspects and possible effects are described.

Although various ITS have been applied for about fifty years, only in the last two decades have advancements in information and communication technologies intensified their application. Meanwhile, an extremely broad variety of ITS exist. Not only are there very different applications but often also a variety of technical solutions to each of them. Furthermore, ITS are employed in many modes of transport. As a result, any generalization is practically impossible. Attempts to do so mostly characterize ITS as significantly cheaper than conventional transportation projects, and find that the effects are more difficult to trace; they may be either small, or commonly agreed upon measurement techniques have not been found, or both. Additionally, a stagnation of advancements in ITS is not conceivable. Many authors agree that there is currently little known about the effects and effectiveness of ITS. Due to its continued development, this will most likely remain an issue for some time. A further aspect which is often more complicated with ITS projects than regarding conventional transportation projects is the identification of stakeholders bearing the project's effects. Due to outsourcing and privatization, the situation has become more complicated in the transportation sector as a whole. However, ITS are not only situated in this framework but also there is no general rule on stakeholders bearing costs and those benefiting from an ITS, neither from a functional point of view nor regarding clear roles for public and private stakeholders.

Research on evaluation methods included resolving fundamental issues. In this respect the link between the theory on evaluation and the rational decision-making approach was established, as well as the importance of stakeholder specific goals which determine the objectives of the evaluation. On this basis, a series of evaluation methods was identified which were to be presented in a more detailed way. These methods originate from different academic disciplines. The available literature appeared to be strongly segmented, focusing on single methods or groups of methods with a similar origin or objective. Here the attempt was made to go beyond these margins. Within the methods of entrepreneurial project valuation different levels of complexity of evaluation methods are explained. Beyond internal considerations of the stakeholder controlling the project, six other methods were presented as listed below.

- Cost-benefit analysis (CBA), to determine the economic desirability on a social level.
- Analysis of value added (AVA), addressing the consequences of the economic activity of the project in terms of value added and employment effects in a region.
- Fiscal impact analysis (FIA), assessing a project's effects on budgets of territorial agencies.
- Cost-effectiveness analysis (CEA) which compares non-monetary effectiveness measures with monetary costs.
- Multi-objective analysis (MOA) allows a project to be evaluated towards its contribution to various goals at the same time. The result may be aggregated to a single indicator. Another common term for this method is multi-criteria analysis (MCA).
- Environmental impact assessment (EIA) to determine problematic effects of the project on the environment.

This short list reveals some of the relevant strengths of these methods. In the analysis it was found that each strength is paralleled by specific problems. Hence, there is not one method that is superior to the others, regardless of the evaluation objective. If evaluation is to be more comprehensive than permitted by a single method, various methods may be combined. Two examples were presented: an approach developed for the evaluation of infrastructure projects in the German Federal Transportation Infrastructure Plan 2003 and the hierarchical economic analysis.

For the demonstration of how ITS projects have been evaluated in practice so far, very different cases were chosen to reflect both the heterogeneity of ITS projects and evaluation methods. The three examples are:

- A stand alone cost-benefit analysis of a freeway traffic management system in Tyrol
- A hierarchical economic analysis of a multimodal urban traffic management system in the city of Cologne
- A multi-objective analysis of advanced driver assistance systems without regional scale based on experiences in various European countries.

Analyzing these cases has been a challenge, as available information on the evaluations is rather scarce. Also, in some cases it proved to be difficult to identify the important facts within the complexity of the reports. Interesting contemplations on each case were nonetheless possible. Further, especially when monetary methods are applied, they are strongly influenced by the established evaluation guidelines for conventional transportation projects.

ITS projects may be relatively small regarding costs and effects when compared to conventional transportation projects. However, the effort of evaluations is great due to the heterogeneity of ITS, the characteristics of the projects and the relatively little available experience with effects. These facts, among others, signify unfavorable conditions for the comprehensive evaluation of ITS with the presented methods. On the other hand, ITS may in some cases substitute for conventional transportation projects meaning that they have to be compared against each other. Equally reliable evaluation results are thus imperative for adequate decision-making. Especially since indications exist that ITS projects are highly efficient, this should be further tested.

Kurzfassung

Entscheidungen über technische Projekte in der Verkehrsplanung sind häufig komplex. Der Unterstützung durch strukturierte Analyse und Vergleiche von alternativen Projekten kommt daher eine erhöhte Bedeutung zu. In den vergangenen zwei Jahrzehnten war ein Aufschwung der Anwendung der Verkehrstelematik als sogenannte intelligente Transportsysteme (ITS) feststellbar. Die vorliegende Diplomarbeit befasst sich mit der Fragestellung, wie Projekte im Bereich der ITS bewertet werden können und wie sich die Praxis der Projektbewertung gestaltet.

Zu diesem Zweck werden zunächst die Charakteristika und möglichen Wirkungen von ITS genauer betrachtet. In einem zweiten Schritt werden verschiedene Bewertungsmethoden untersucht, die gegenwärtig für Bewertungen von Verkehrsprojekten eingesetzt werden. Dabei stellt sich die Frage nach deren Vor- und Nachteilen sowie der Anwendbarkeit auf ITS. Der dritte Abschnitt widmet sich der Analyse der Bewertungspraxis. Auf Grundlage von drei ITS-Projektbewertungen, welche im Verlauf der letzten Jahre von Experten durchgeführt und publiziert wurden, soll festgestellt werden, welche Methoden zur Anwendung kommen und welche Probleme sich dabei stellen, die eventuell nicht in der Theorie behandelt werden.

Es wurde festgestellt, dass es sich bei ITS um eine sehr heterogene Gruppe technischer Projekte handelt. Hinzu kommt ein hoher Komplexitätsgrad, der sich aus der Verbindung von Verkehrssystem, technischen ITS Komponenten, Datenverarbeitung und ITS-Diensten sowie den betroffenen Akteuren ergibt. Des Weiteren stellte sich heraus, dass ITS neben den häufig im Zusammenhang von Verkehrsprojekten auftretenden Effekten auch Wirkungen haben, für die es zurzeit keine gemeinhin anerkannten Messmethoden gibt. Die genannten Umstände bedingen, dass die Bewertung von ITS Projekten aufwändiger ist als wenn auf zahlreiche Erfahrungen und standardisierte Vorgaben zurückgegriffen werden kann.

In der Analyse von sieben Bewertungsmethoden ergab sich, dass keine Methode gegenüber den anderen eindeutig besser ist. In jedem Fall wurden Stärken und Schwächen gefunden. Allein im Zusammenhang mit dem Bewertungsinteresse lässt sich der einen oder anderen Methode der Vorzug geben. Ist eine umfassendere Bewertung vonnöten, können mehrere Methoden komplementär angewendet werden. Zwei solcher Ansätze werden dargestellt.

Dass viele der theoretisch beschriebenen Methoden praktische Anwendung zur Bewertung von ITS finden, zeigt sich in den Fallbeispielen. Teilweise orientieren sich die Ansätze stark an Richtlinien zur Bewertung von Verkehrsprojekten im Allgemeinen und gehen nicht auf mögliche Eigenheiten von ITS ein. Ansätze zur Kritik lassen sich vor allem bei den Annahmen und der Erstellung der Eingangsvariablen finden. Die Anwendung der Methodik erscheint weitgehend unproblematisch.

Die Ausgangslage für die Projektbewertung von ITS erscheint aufgrund zahlreicher Probleme durch ITS Charakteristika und hoher Komplexität der Methoden schwierig. Nachdem es Indizien für eine hohe Effizienz von ITS und weitere positive Wirksamkeiten gibt, sollte auf die Bewertung zur weiteren Aufklärung, ob die Projekte wünschenswert sind, jedoch nicht verzichtet werden.

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1 Introduction

1.1 A statement of the problem

Decisions are the turning points between the conceptive planning process and the actual execution of an activity, such as the implementation of a project. They are the most important steps. The source of any situation where a decision is necessary is the availability of at least two options. Practically, every decision in planning is of such character that doing nothing, or better, maintaining present operations is always an option. On the other hand, it is also possible that a large number of alternatives present themselves. The need to decide occurs under circumstances of limited resources, when it is not possible to realize all proposed activities. Equally, in case of tradeoffs between effects which are associated with one of the alternatives and of which some may be perceived as positive and others as negative, a solution has to be found.

In these instances, future developments are predetermined to a large extent. It is therefore important to make the best possible decisions. However, in most cases it is not obvious which choice satisfies this requirement; sometimes it will not even be clear according to which aspects the available alternatives shall be assessed. Moreover, the quality of a decision may be perceived contrarily by different individuals or groups. The perception in this case is strongly influenced by the interest of the involved parties. In many cases, it may only be possible to determine for whom a given action is favorable or not.

Two criteria may be established regarding the quality of a decision: If the perceived positive effects of the result of the selected option outweigh the perceived negative effects, the decision leading to this result may be denominated a good decision. Further, a good decision is distinguished by its lasting character. If a decision does not have to be revised, this is an indication of its quality.

Any individual or a group may face the need to decide but, as described, in many cases arriving at a decision is not easy. Especially when contradicting interests arise (which is often the case when more than one individual is involved) the process becomes more complicated. Also, decisions tend to be more difficult as the dimensions and complexity of the project increase. This may be the case if individuals or private organizations have to decide, but it is practically inherent to most problems dealt with in the public sector. Developments such as the phenomena of increased autonomy and delegation of activities of public agencies, as well as increased importance of multi-layer systems make adequate analysis of effects a necessity (Widmer & Leeuw 2009, p.70). The assessment of effects and structured, transparent examination of the importance of these effects – in short: evaluation – is an important aid for decision-makers in any situation.

As these basic concepts have been elaborated, the question follows as to how to conduct such evaluative processes; even more demanding, how can it be ascertained that the best alternatives are determined? A significant amount of thought and resources has been dedicated to this task in research and, equally, the practice of analysis. The problem and approaches to its solution appear in many situations of our lives. A large variety of theoretical constructs have been developed which

deal with the issue both normatively and positively and try to explain decision-making and the preceding steps. These constructs use various subject matters and their associated paradigms as their point of departure. Both the practically applied and the theoretical constructs may be differentiated between those treating the actual process of decision-making and others focusing on issues on the preparatory and supportive plain. Preceding decisions, a series of steps is necessary beginning with the identification of problems, objectives and constraints. In the following system design phase, the present situation is described, activities are conceived, e.g. projects and alternatives. Here, feasibility studies are of importance where the technical practicability, legal or economic viability and social or environmental tolerability are verified. Finally the concept of evaluation appears. In a narrow sense, it is described as the *"comparison of alternative solutions"* (Cascetta 2009, fig.1.9). Mostly, however, the evaluation process will not rely exclusively on the information produced in the precedent stages, as these may not be sufficient or sufficiently adaptable. Hence, evaluation in a broader meaning generally includes the process of gathering and organizing the necessary data. Stockmann (2007, p.25) defines that, in a general sense, evaluations are an appraisal or valuation of a circumstance or object based on information. Further specification of the issue must include that an evaluation may influence, but does not constitute the decision itself. At the same time, it is independent of the implementation process. The principal function of evaluation is the support of decisions which may also include analyses posterior to the execution of activities.

As described above, decision-situations become more complicated as activities involve large numbers of stakeholders and generate many or contradicting effects. Evaluation is especially necessary in these cases. A field where these characteristics recurrently pertain to projects is transportation. Consequently, a remarkable pool of adapted concepts as well as performed evaluations may be found in this context. Also, transportation projects are a paramount issue in urban and regional planning: they significantly change the exploitability of a location's potentials, they determine to a large extent the options of how people can use space and they have an important role in making economic development possible. Transportation projects are intrinsically related to the central problems in urban and regional planning. Their evaluation, which may increase the quality of decisions, hence becomes an important issue not only for transportation engineers but also in urban and regional planning. This is especially true in the light of the ever growing awareness regarding the necessity for sustainability. Projects in the field of transportation bear the potential of contributing vastly to objectives of a sustainable development and environmental protection. At the same time, they may contradict goals in these areas.

The bulk of the work in transportation project evaluation has been, and most likely will continue to be done in relation to constructional expansion of transportation infrastructure. However, measures of management and optimization within the existing system are becoming more attractive. On the one hand, management and optimization projects are supposed to significantly ameliorate problems of existing transportation systems. Additionally, they are sometimes even praised to have the potential to substitute or postpone further constructional expansions, implying that commitment of resources may be avoided. On the other hand, due to technological advances, previously envisioned but unachievable management and optimization measures become realizable. Especially the concurrent increase in performance and decrease in costs of information and communication

technologies (ICT), and associated with it, the advances in information gathering and processing, are decisive factors. The latest development is rooted in advances in wireless communications. One of the manifestations is the nearly ubiquitous availability of high volumes of data transfers due to enhanced wireless communication networks and portable devices[1] offering a large variety of functionalities. A growing familiarity of the general public with the operation of ICT and the increasing demand for information makes this trend possible. The beginning of a boost to transport related applications on portable devices owned by individuals is discernible. Yet this is only one indication of the many possibilities in transportation management and optimization projects. Here, the technical field of so called intelligent transportation systems (ITS) – which basically attempt to use the possibilities of ICT to enhance the transportation system – seem to bear great potential.

Various institutions highlight hopes placed in of its, that they can help to solve recurrent problems in transportation such as the inefficiencies associated with congestion, losses from accidents or environmental impacts. Policy documents (for an example see EUROCITIES 2010, p.1) and the reports by public controlling agencies (e.g. Rechnungshof 2009, p.155) see ITS measures as a key instrument in the future development of transportation systems. Technical reports also seem to support the aspirations.

In the light of this topicality of ITS and the elaborated importance of project evaluation, this thesis is developed. The central question in this thesis is how measures in the field of ITS may be evaluated. To further focus the work, a more detailed set of research questions is formulated:

- What are the effects of ITS projects which will constitute inputs in an evaluation?
  - How can these variables be identified?
  - How may they be described?
- Which methods are commonly used to evaluate transportation projects?
  - What are the advantages and disadvantages of these commonly applied methods?
  - What issues must be respected when interpreting the result?
  - Which approaches have been developed to overcome deficiencies of certain evaluation methods?
- How have ITS projects been evaluated in practice?

[1] Information provided by the US DOT depicts an increase from 18 mobile wireless devices per 100 persons in developed countries in 1997 to 97 in 2007. The number of mobile phones with Global Positioning System functions sold by 4 important companies are expected to rise from below 50 million units in 2007 to about 380 million units in 2015. (RITA, ITS Joint Programs Office 2010, fig.1 and fig. 2)

1.2 Scope and methodology

1.2.1 Scope

In this thesis, the methodology of evaluation is of central interest. As indicated in the previous section 1.1, evaluation does not constitute a decision. Thus, neither the process and theory of decision-making nor concepts of implementation are a major subject in this thesis. Also, the steps preceding the actual evaluation such as feasibility studies and techniques of measurement of effects are not the core issue. Nonetheless, a part of the thesis is dedicated to elaborations regarding potential effects and stakeholder identification as they constitute the basis of an evaluation. The actual results of evaluations of ITS are principally a very interesting subject but, as far as the result is not interpreted in the context of the evaluation method, the actual values are of secondary importance.

It was implicitly stated in section 1.1 that practically any activity can be evaluated. This would include policy development or research programs as well as technical projects. As such a vast area cannot be covered in a thesis, the scope is limited to evaluations of technical ITS projects. However the level of development of the technical project (the terms strategic, tactical and operational are recurrently used in reference to the level of development) shall not be a basis for restrictions.

Research has disclosed an overwhelming variety of evaluation methods. At the same time it was found that the classifications of qualitative and quantitative evaluation were neither stringently used, nor could a reasonable definition be established as many evaluations combine quantitative elements and qualitative descriptions or even attempt to operationalize qualitative information. The focus of the research was directed at evaluation methods with an emphasis on quantitative techniques as it is assumed that the numerical structuring leads towards a more explicit result. Methods with an exclusive focus on qualitative descriptions[2] are not regarded.

Transportation is strongly segmented through the different modes of traffic and further through the differentiation between movement of persons or goods. ITS are applied in any mode. The focus of this thesis is set on ground transportation, which is defined as the sum of non motorized traffic plus road and rail traffic, to allow for a more profound analysis. Air, maritime and pipeline transportation each have very unique characteristics, for example, in terms of the market segments they are aimed at or the stakeholders involved. A comparison with the ground transportation modes would probably be inconclusive and is therefore omitted. Within ground transportation there are no other limits defined in terms of traffic modes, market segments or the purposes of trips. Breaking down the system of ground transportation is difficult because of strong interrelations of the subsystems and modes. For the task of evaluating overall social consequences of ITS, it would most likely not suffice to look at a single subsystem. Thus, also for the research regarding evaluation methods, this rather narrow perception shall be avoided.

[2] A concise overview of common qualitative evaluation methods in transportation is provided in Cerwenka et al. (2007).

Spatial/Regional:

On the regional level, there were no confines set for the sources of theoretic literature. A certain emphasis is dictated by the constraint of the availability of documents and the language of the publication. The examples of conducted project evaluations used in chapter 4 were to be related to projects in Europe or North America.

Temporal:

There were no temporal limits set to the origin of sources for theoretic research. However, it was the author's ambition to take the most recent developments into account, if possible. Examples of conducted project evaluations were not to be older than ten years. Thus, only documents published as of the year 2000 were taken into account.

1.2.2 Concept and method

As for the method of research, this thesis is limited to research in literature and the reflection of the findings. It is not part of this thesis to conduct a practical example of a project evaluation.

The concept largely follows the research questions stated in section 1.1. The concept arranges the thesis into two parts. The first part, consisting of chapters 2 and 3 is dedicated to an assessment of evaluation methods and an analysis of critical issues regarding ITS in this context. Here, a normative interest shall be satisfied regarding the theoretical suggestions on how evaluation can or should be done considering circumstances.

The objective of chapter 2 is to introduce the concept of ITS and describe the significant characteristics of such systems. This is done from a technical point of view and the socio-economic aspects are also covered. It further includes contemplations on the potential effects of ITS projects. The next step is dedicated to the identification of the stakeholders in ITS projects, as in some evaluations it is of importance where effects occur, that is, who may benefit and who incurs costs or negative effects. This includes suggestions on how to categorize the stakeholders and provides details for the case of Austria. Finally, approaches to compile and structure the actual effects of ITS are illustrated. Departing from a suggestion on how to identify the relevant effects, a set of characteristics is explained which may be used to categorize the effects. This is followed by an account of effects which are proposed or have frequently been applied in evaluations of ITS projects.

As the necessary information to comprehend ITS, whereupon also an effect analysis may be based, has been presented, the 3rd chapter is dedicated exclusively to the methodology of evaluations. The first section takes as its point of departure the elaborations in the statement of the problem section 1.1 and provides more detailed insights regarding the situation of evaluations in the process of establishing projects and the motivations and necessities to evaluate. Also a first illustrative overview of evaluation methods is given. A large part of this chapter is dedicated to the explanation of a variety of selected quantitatively based evaluation methods which are subsequently compared against each other regarding their strengths and disadvantages. Associated with the method of cost-benefit analysis, the technique of monetization is treated in an excursus. Important insights regarding the issue of discounting are equally conveyed in an excursus. To conclude the theoretical

treatment of evaluation, concepts which attempt to remedy the disadvantages associated with certain evaluation methods through combination are presented.

The above mentioned second part of the thesis is contained in chapter 4. It provides insights regarding the actual practice of project evaluations in the area of ITS. Towards this task, a set of published evaluations of ITS-projects conducted by experts is analyzed. From the pool of evaluations established by research, a set of three cases is chosen. The selection of the cases achieves the greatest possible variety within the defined scope of the thesis regarding both the evaluation methods and the technical projects evaluated. This approach is opposed to a comparative analysis of similar cases. However, as the thesis' normative first part provides an extensive basis for comparisons, it was found that an additional quality could be provided in the case studies part; by analyzing three dissimilar cases, a more comprehensive description of the state of the evaluation practice may be conveyed. The aspiration to further provide variation of the cases regarding their geographical origin, for example to demonstrate differences between North American and European evaluation approaches was not realizable due to a lack of sufficiently documented ITS evaluations meeting the other selection criteria. The main objective is to provide a description of which methods are actually applied and how.

Definitions of the relevant terms are generally established in the text, associated with the appearance of the term.

It was found that in discussions regarding both the field of ITS and evaluation methods, the academic and professional vocabulary is highly heterogeneous. To make the elaborations in this thesis as clear as possible, only one term is used stringently for a concept – even if cited publications prefer other variations on the terms. All of these cases are highlighted and the original term is indicated. Thus orientation in the respective publications shall be facilitated for the interested reader to allow proper reviews and research departing from the present text. In all cases, great care was taken to verify the analogousness of the terms.

2 Characterization of Intelligent Transportation Systems (ITS)

2.1 Characteristics of ITS

2.1.1 Definition and overview of intelligent transportation systems

The term intelligent transportation systems (ITS), also intelligent transport systems, is rarely used outside a highly specialized community of ICT developers, researchers and transportation planners. It is an abstract, composite term which is not supportive of intuitive understanding. This section is dedicated to providing an overview of what ITS can be.

Although ITS measures have been applied for decades, scholarly textbooks in the field of transportation studies so far do not treat the subject prominently. The earliest application of an actuated traffic light dates back to as far as 1928, but only in the 1960s were computers first used in traffic control operations (Gillen & Levinson 2004, p.2). Traffic guidance facilities for example, which today would also be categorized as ITS, were first implemented on German highways in 1976 (Hampe et al. 1981, p.11), other types of measures most likely even before that. Further, it can be distinguished that automation of traffic control and integration of telecommunication devices have long been common in aviation, maritime and waterways and rail modes. Reasons for this may be the extremely high cost of single accident events, and the institutional generation of transportation services. Also, the high complexity of systems was not a major issue since they would only have to be operated by a small number of trained professionals.

Definitions of ITS remain mostly vague. In part, this is linked to the broadness of the area of activities the term should cover, but the inconclusiveness is also due to the use of relative terms in the published texts such as “modern” or “advanced” (Bobinger & Keller 2007, p.102; RITA n.d.). The common element is the integration of IT with the transportation system; however, most publications establish a proper, slightly modified definition.

Since no commonly agreed upon definition was found, the following is established based on the research and experience of the author:

An intelligent transportation system is a technical measure, the functionality of which intentionally affects the transportation system. An ITS does not move persons or goods. An ITS consists of one or various interlinked electronic devices capable of gathering data, data processing and/or data transmission, allowing autonomous or dynamic actions of the system. The ITS intends to reduce the effort or risk of using, controlling or maintaining the transportation system, gathering information or making decisions.

Synonymous to ITS, the term transportation telematics is often used, especially in Europe (Keller 2003, p.2; Šitavancová & Hájek 2009, p.17). Telematics was preferred e.g. in the German language area in the last decade where it is dominant in important official documents. As the term ITS has also been introduced to languages other than English, its usage has increased lately. This is

probably due to increasing internationalization of technical language and research. As ITS is the internationally favored term for the technical systems, the evaluation of which is the subject of this thesis, it will consequently be used here as the preferred umbrella term, although it may also be viewed critically[3].

Table 1: Overview of ITS applications

Application	*Based in* [a]	*Orientation* [b]	*Usage*
Information management	Infrastructure	Infstr.-operator	
(Road)way operations & maintenance	Infrastructure	Infstr.-operator	
Traffic management [c]	Infrastructure	User/ Infstr.-operator	pre-/on-trip
Electronic payment & pricing	Infrastructure	Infstr.-operator/user	on-trip
Traveler information	Infrastructure	User	pre-/on-trip
Road weather management	Infrastructure	Infstr.-operator/user	on-trip
Crash prevention & safety	Infrastructure	User	on-trip
Driver assistance	Vehicle only	User	on-trip
Collision avoidance	Vehicle only	User	on-trip
Collision notification	Vehicle only	User	on-trip
Traffic incident management	Infrastructure	Infstr.-operator	
Emergency management	Infrastructure	Infstr.-operator	
Commercial vehicle operations	Infrastructure	User	pre-/on-trip
Intermodal freight	Infrastructure	Infstr.-operator	

[a] It is understood that vehicles in some contexts are perceived as part of the infrastructure. Thus ITS based in infrastructure may include components built into vehicles. ITS applications marked as based in "vehicles only" do not rely on external infrastructure. However it may be the case that certain variations of the application include components integrated with the static infrastructure.
[b] Groups of stakeholders here are formed based on their relation to the transportation system, in contrast to 2.2 where stakeholders are categorized by their relation to ITS. Here users includes travelers and institutional users of transportation systems; operators are institutions in charge of development and maintenance of transportation infrastructure and control traffic.
[c] Aggregation of transit management, arterial management and highway management

Source: Author, list of applications largely based on RITA 2009

For a more practical understanding, Table 1 contains an overview of ITS applications. Additional information is provided regarding the technical implementation, which stakeholder will mainly benefit from the system and when it is activated during a trip. All of these items may be used to categorize ITS applications. The list here is sorted according to functional premises, e.g. information, safety, management of operations. Each of the applications listed here is an umbrella term for a variety of functions[4], which again may be implemented in various constellations of technical components. The overview demonstrates the difficulty of understanding ITS. It is not limited to any mode or trip purpose and is strongly related to other technical disciplines.

[3] For further elaboration on the issue see subsection 2.1.3.
[4] Detailed overviews may be derived from ITS architectures which are available online. See: http://www.frame-online.net for the European construct, or alternatively http://www.iteris.com/itsarch/html/user/userserv.htm or http://www.iteris.com/itsarch/html/mp/mpindex.htm for the US system.

Thorough reflection also has to determine which measures do not qualify as ITS. According to the definition stated above one could ask: Is a traffic light an ITS since it influences traffic flows while employing electronic equipment to achieve this? The answer in this case depends on the specific configuration of the traffic signal. If the installation is not equipped with any further components that allow it to react or be dynamically adapted to actual traffic conditions it does not count as an ITS. Nowadays, especially in larger agglomerations, many traffic signals are connected to a central control station, making them part of an ITS. In these cases, the traffic signal constitutes the user interface. A more detailed insight into the components of ITS is provided in subsection 2.1.3.

2.1.2 Goals of ITS measures

The analysis of goals is important in three ways. First, a set of goals describes the intentions of a measure and thus is part of the definition. Second, some evaluation methods measure the quality of a system by determining the contribution to a set of goals. Chapter 3 will provide further insight in this respect. Finally, the goals for a measure provide a good point of departure for the analysis of its effects, as described under 2.3.1.

Three important goals are recurrently listed for ITS measures in policy documents[5]:

- Optimizing use of the transportation system towards more efficiency[6]
- Enhancing safety of the/a transportation (sub)system
- Enhancing the accessibility of the/a transportation (sub)system by making it more comfortable and or practicable to use

As ITS measures improve the transportation system, they also contribute to the goals of the transportation system in general. Some ITS may even be seen as enabling technologies only; while they make developments in the transportation possible, they are not attributed a proper set of goals other than that. The primary objective of any transportation system is to facilitate movement of persons and goods. The mobility of people and goods is one of the pillars of economic development. Economic development in turn is an important element of a society's standard of living which in turn influences the quality of life. These relations mean that many ITS also contribute to the high level objective of increasing the well being in society.

ITS may also affect other systems other than the transportation system such as the economy, societal constellations or the environment. Hence, ITS may also contribute to achieve goals in these systems. The following items present the more relevant issues, although the list does not claim to be exhaustive.

[5] The primary sources for this compilation were the Austrian Telematics Framework Plan (Pfliegl et al. 2004, pp.2,7f.,11ff.), the US National ITS Architecture as described in Nakanishi (2004, p.3f.) and the European Union policies for transportation (EC 2006, p.3f.; EC 2008a, p.2).

[6] ITS may contribute to the efficiency of the transportation system in many ways, for example by increasing productivity in operations or enabling temporal or modal redistribution of traffic. Another efficiency issue is the reduction of energy consumption or environmental costs. Here, no extra goal is defined regarding this issue as it is assumed part of the general issue of efficiency in transportation. Some policy documents nevertheless highlight the environmental aspect of sustainability by listing it as an extra goal. This can be especially found in EU documents.

- Increase of transparency in the transportation sector: Based on detailed data generated by ITS, actual current levels of transportation services provided and public funding levels may be more precisely described.
- Increasing the quality of transportation planning decisions: The above described knowledge gained about the transportation system can be used to better customize planning measures to given situations. Additionally, higher quality of information used as an input in evaluations and decision making processes can also lead to superior or at least more conscious decisions.
- Promotion of economic development in high tech industry. Through the intense use of technology and the enabling of new transportation service concepts, the decision to implement ITS may also constitute a boost to the high tech industries. Additional revenue opportunities are created as the transportation sector becomes a new exploitable market.[7] A further consequence may be new jobs in these sectors.
- Increased security and reduced infringements: Since some ITS are dedicated towards traveler security, surveillance or the tracking of goods, they may also serve goals in combating crime or fraud.

2.1.3 Technical description of ITS measures

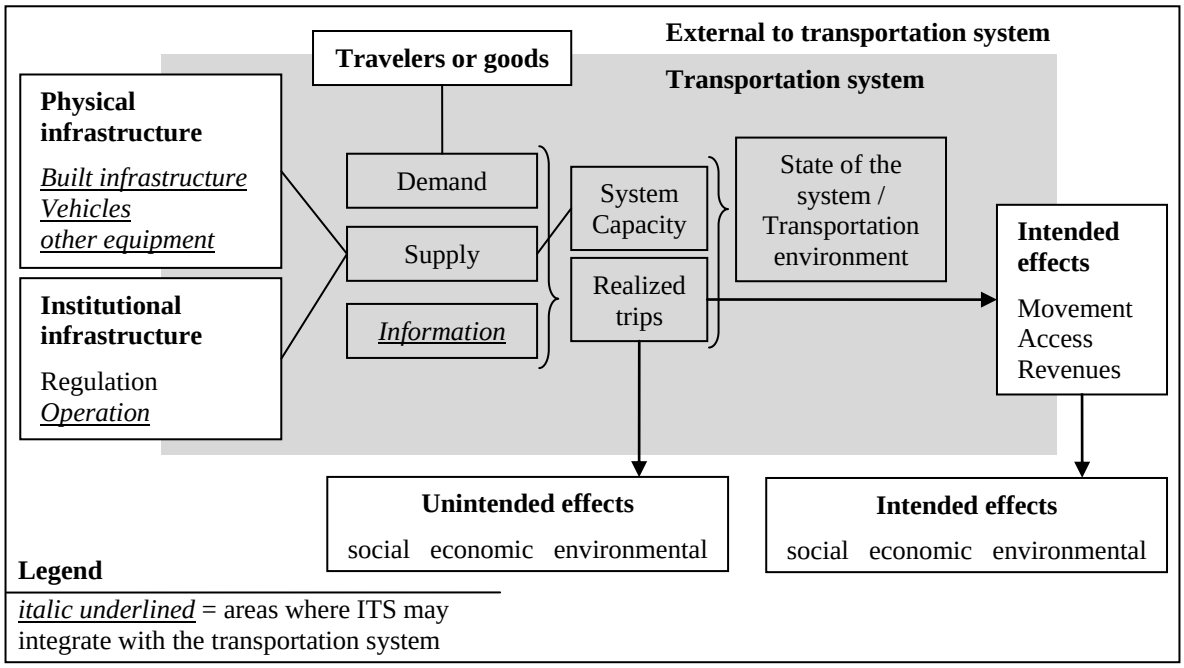
A characteristic of all ITS is that they do not actually move people or goods. Consequently, an ITS only produces the most desired effects if it is integrated into the transportation system. There, it influences the parameters of the system's elements. Figure 1 represents the functional chain of the transportation system. The system elements where ITS may be integrated are marked. Of course, not every ITS application acts on all of the marked components of the transportation system. Generally, at least one component of an ITS is integrated with an elements of the physical infrastructure of the transportation system. Usually these will be sensors which measure the state of the transportation system (in the case of infrastructure based sensors) or the transportation environment (in the case of vehicle based sensors), actuation or information devices.

Another conclusion that may be derived from Figure 1 is that effects mainly intend to enhance the primary function of the transportation system which is providing access to a location. This is coherent with the goals, as stated in 2.1.2. The input of time and energy into, and the risk of use of the transportation system shall be reduced. In a short term analysis, this is always a very positive aspect. However, long term analyses are also necessary to determine whether the positive effects are compensated or in the worst case overcompensated. An enhanced system may attract additional users or induce further trips. This is problematic if the transportation mode in question has significant negative side effects.

[7] The involvement of the high tech sector is viewed critically by some. The argument is based on the assumption that ITS are ineffective in achieving important goals related to the conditions that mobility must be realized in a socially and environmentally sustainable way. In this context ITS just represent another hollow promise which results in prolonging important structural changes in the transportation system. At the same time, as the high tech industry exploits the new market, another lobbying group without interest becomes a stakeholder; as profits grow the interest for structural changes declines. This chain of arguments is presented by Knoflacher (2007, p.154).

Most ITS are not primarily dedicated to remedy environmental problems. If, through the reduced consumption of fuels in an ITS enhanced transportation system, positive environmental effects occur, this is, although positive, mostly a side effect. ITS that are conceived to solve environmental problems do exist. Examples would be in intelligent vehicle systems reducing emissions, systems dedicated explicitly towards inducing modal shifts towards environmentally friendly transportation modes or corridor control systems deriving their signals from emission monitoring systems. At least for the latter case, an application is known to have been installed (ASFINAG n.d.). But even these systems are rare (Rechnungshof 2009, p.163) and inauguration in this specific case was caught up in a set of regulatory problems[8]. The situation is similar regarding technical ITS applications aimed at increasing equal access to transportation opportunities for minority groups in society. In both cases, dedicated ITS are currently under development but very few have so far been implemented. Since evaluation is often directed at future projects, these developments should be treated with special care.

Figure 1: Integration of ITS with the transportation system



Source: Author

Following the definition established in subsection 2.1.1, the handling of information is the central element of an ITS. As stated by Haynes & Li (2004, p.130), information and communication must be central aspects in an evaluation of ITS. The technical construction of ITS is oriented toward this task and generally consists of four components: automated sensors gathering data, data processing and storage units, components to communicate information[9] or which automatically act on it, and finally, means of transferring the data between the components. The way these components are arranged varies greatly as does the physical manifestation of the components. The ITS architecture developed in the U.S. distinguishes between the spheres of technical components making up a system (physical architecture) and the processes necessary to provide the functionalities (logical

[8] Parts of the system had to be uninstalled without ever being brought into service because of the absence of a legal basis. (ORF 2009)

[9] It is assumed that processed data conveys information.

architecture) (ITSERIS 2009). An interesting issue is also the human involvement in ITS. Some ITS only aim to enhance the quality of human intervention in the transportation system, e.g. traffic management systems. At the same time, control and decision making are left to human operators.[10]

Three examples will shed further light on the technology of ITS: An adaptive signal priority system conceived by PATH, to reduce time loss of busses at traffic signals, uses vehicle based devices that determine the bus' location via GPS. This data is then wirelessly transmitted to an operations center where, the bus movement data is compared with stored references. The bus arrival at the intersection is then estimated and a signaling priority request sent to the traffic light controller. There, the actual traffic situation is taken into account which is determined by loop detectors. Accordingly, a signaling scheme is computed which minimizes delays for other traffic flows while giving the bus a priority signal. Finally, the traffic lights are controlled according to the calculations (Zhang & Shladover 2006, p.25 f.). In this case sensors are mounted on vehicles as well as in the infrastructure. Data from the vehicles is transmitted wirelessly to the first processing stage. Data from the roadside infrastructure sensors and the actual command to the traffic signal will most likely be transmitted by wire. Finally, the information is relayed visually to the users of the transportation system: stop or go through the influenced traffic light. This demonstrates the various possibilities of data transfer between geographically separated entities constituting the system.

In the second case described, all components are mounted within a vehicle. A driver assistance system identifying dangerous driving conditions as, proposed by Fang et al. (2009, p.791) uses the data feeds from various sensors. Processing incorporates a detection function and a function to generate a warning signal for the driver. In theory, all the data could be generated by onboard sensors, processed by an onboard unit and communicated visually or acoustically, probably even employing tactile user interfaces. Potentially, the signal could also be sent to an actuation device with direct effect on the vehicle's path without involvement of the driver. The system would be autonomous and not communicate with other vehicles or incorporate external information. Of course, it is possible to envision that the system also draws on data provided externally (e.g. wireless road weather information).

Just as the arrangement of components varies, so do their physical manifestations; some, in fact, are only virtual. A traveler information system is an example of this. The online passenger information system presented by Zografos et al. (2009) for example provides all kinds of trip planning, booking, and real time information. The information may be accessed via the internet and specific en-route updates can be sent to mobile phones via SMS. In both cases, the entity displaying the information is not dedicated to this exclusively or principally[11]. The final system component

[10] Most systems of this kind are termed intelligent transportation systems. As they fulfill the requirements of the definition (e.g. gathering of data, data transmission, data processing, relaying of information, …) this is correct. However, a certain doubt about the "intelligence" of such a technical system is appropriate since they are not able to react to changed situations; not even within a strongly delimited environment. Instead they rely on human intelligence and are a mere support for intelligent human actions or reactions. It is assumed that the term "intelligent" is alienated in the context. As "intelligent" transportation systems is the term used in international research and transportation planning it was decided to also use it here.

[11] This differentiation is important when deciding in how far costs of system components shall be attributed to the ITS.

communicating information to the user is therefore the website or the message. The real time information may also be displayed on dedicated “Terminal Notice Boards”. In this case, the display has to be viewed as a component of the ITS.

For further details, the reader shall be once more directed to the “ITS Architectures”. These high level schemes are usually constructed on a national basis. The European case is special in this aspect as the national states develop architectures, which are based on a system established at the level of the EU[12]. The architectures are constantly being expanded and the U.S. architecture is beginning to integrate information on standards for ITS. From the complexity of ITS’ technical structure arises the issue of interoperability. Thus, establishing technical standards is an important issue. The standards may also play an important role in evaluating an ITS, first as a technical reference and second, an ITS based on standards may have lower development risks or higher potentials in application. Equally, if ITS are developed departing from the relevant architectures they are likely to better fulfill user needs. This makes them more successful, an important factor in evaluation.

One of the principal problems in transportation planning is the dimensioning of the infrastructure and/or service to adequately address demand. ITS do not directly address the issue of capacity but rather enhance a given infrastructure or service. In other words, they optimize usage of a given capacity. Nevertheless, some measures, e.g. ramp metering on a single link or variable guidance signs in a network, may increase traffic volume on the link or the network. Estimates for freeways suggest potentials of 5 to 10 percent (Ausserer et al. 2006, p.53). This must be detailed for each case specifically. An overall statement is not possible.

Within the ITS applications, there is a large variety of components and system configurations that are able to provide comparable functions. The costs of the different implementation options may vary greatly. For a speed probing sensory system, Houston TranStar for example compared traditional automated vehicle identification systems with Bluetooth sensors. The installation cost of the Bluetooth devices was just 1,5% of the cost of the other ITS system. ("Cost-Benefit Analysis" 2010, p.23) In project evaluations, it is hence advisable to regard the magnitude of costs of project alternatives with special sensitivity.

To conclude the technical description of ITS, another issue shall be brought up. For the analysis of a project, it will be important if it is the technical components of an ITS which, through their operation, directly induce the desired effects. Driver assistance systems would qualify as such, to provide one example. Alternately, ITS may only be the enabling technology, making other measures possible. For example, a road pricing system may incorporate ITS for different purposes. Effects of the pricing measure should not be attributed to the ITS system. On the other hand, if construction and operational costs of manual tolling are saved by the operator and travelers enjoy reduced clearance times in comparison to non ITS tolling, those effects should be attributed to the technical measure. Not all cases will allow such a clear disaggregation. A definition will have to be found specifically for each project. In evaluation, the matter becomes a problem of correctly

[12] For references see footnote 4.

establishing the reference and planning cases which are compared against each other so the effects of the ITS may be distilled.

2.1.4 Socio-economic description of ITS measures

The transportation system and also ITS are socio-technical systems. In this subsection the factors that influence interactions of humans with ITS shall be described. Also, the characteristics of an ITS as an economic good have to be respected in evaluations. These issues largely determine if and to whom effects occur.

Economic Characteristics of the Good "ITS"

Economic theory suggests that market mechanisms lead to Pareto efficient allocation[13]. If market failures are prevalent, this prevents efficient allocation. Market failures may be the result of certain characteristics of a good as described in the following paragraphs for ITS functionalities. Alternatively, other distortions such as missing information may cause market inefficiencies. In that matter, ITS can contribute to the quantity and quality of the information available to agents. Complete information however is likely to remain a theoretical construct.

One of the most important issues in economics is to differentiate between public and private goods. Public goods are characterized by non-rivalry or use and consumers cannot be excluded. This leads to difficulties in collecting user charges. Thus it would be impossible for private agents to regain their investment, which makes public intervention necessary if the public good is to be provided. In the case of private goods the situation is reversed. Public action is not necessary and may even be less efficient than private initiatives. Two further categories of goods may be derived where excludability and rivalry of consumption are not at the same time positive or negative. Further explanations may be found in any compendium of economics. The importance to distinguish public and private goods remains.

In the case of ITS, it is not possible to generalize that all ITS functions are either public or private goods. Some applications such as driver assistance systems are clearly private goods. Others, such as traffic management or traffic incident management, may be thought of as public goods. A third example, that of traveler information, demonstrates that technical details matter. Traveler information provided collectively, e.g. at public transit stations, is a public good. Information provided individually, e.g. to computers or mobile devices, may be prone to both rivalry of use[14] and excludability[15]. Consequently it is not possible to state that ITS can only be provided by the public sector or contrarily that public involvement is not necessary at all. A determination is relevant to decide whose interests an evaluation is based on, as demonstrated in 3.1.2.

The functions of some ITS, such as electronic payment and pricing or surveillance techniques, may increase the exclusivity of transportation infrastructures which are generally considered public goods. As indicated in the previous subsection 2.1.3, the pricing measure itself is not an ITS project.

[13] Some scholars such as the Nobel laureate Stiglitz (1991) view this assumption more critically. The discussion is also fueled by the recent financial and economic crisis (Storbeck 2010).
[14] E.g. for bandwidth or service requests.
[15] E.g. user registration, passwords, no service provision without payment.

Another common subject of economics is external effects. An external effect is not felt by the agent causing it. Hence its nature and magnitude do not influence the agent's decision on whether or not to perform the activity causing the effect. This leads to excessive activity in case of negative external effects or too little activity in case of activities generating positive external effects. The latter are often related to public goods. Both positive and negative external effects occur mostly as non-monetary effects.

Most ITS measures produce significant external effects. These may appear in very different ways. A simple example is the increased safety of other traffic system users if a driver uses collision avoidance systems. Since many ITS applications are provided by operators to the users of the transportation system, the benefits to the users should be strictly regarded as external effects to the operator. In case of positive external effects, this may lead to increased ridership and thus create indirect returns to the operator. Thus part of the external effect is internalized. Another case of internalization of positive external effects by operators is charging the users for the service.

However, it is not said that ITS generate only positive external effects. A likely assumption is that the negative effects are of a rather small scale and are mostly consequences of increases of transportation system use and thus occur as secondary effects. Nonetheless negative external effects from ITS should be reflected in the light of evaluations. Currently, ITS are associated with some still unknown effects. This leads to a certain risk of implementing ITS, which should be acknowledged in evaluations.

A very theoretical but illustrative example is the case of wireless communication. To date, it is not ascertained whether wireless communication has a harmful impact or is completely unproblematic. If it should be determined that wireless communication is harmful to living beings the negative external effects of ITS might increase greatly.

Acceptance of ITS and Determinants of Utilization

Without being put to use, a system does not generate its intended effects.[16] ITS are mainly used by transportation infrastructure operators or by users of the transportation system. Although the motivations to implement or use an ITS or not vary, a set of factors influencing decisions can be identified:

- Utility
- Cost
- Reliability
- Current ability to operate ITS devices or comprehend the information and opportunities to learn usage/educate users.
- Issues of privacy in case of individuals, or trade secrets in case of organizations
- Clarity of regulation concerning responsibility in case of system failures with severe consequences

[16] However, it may still require resources and thus be a source of costs or generate unintended effects.

Transportation infrastructure operators perceive increases in operational efficiency, increased control of traffic and user behavior and enhanced response to extraordinary situations as benefits from ITS.

Users of the system may be institutions or individuals as further detailed in section 2.2. Users are entities with needs that they strive to satisfy. They possess resources which may be dedicated to the task according to values and experiences. Based on the needs, the users approach the transportation system with a purpose. The available resources define the options whereas values and experiences constitute preferences. Purpose, options and preferences shape the mobility behavior of a user. This decision point is marked as "Choice M" in Figure 2. As the principal function of the transportation system is the provide persons access to locations and goods, the choice will relate to movement. For the movement, the user expends resources, most importantly time and energy, and incurs risk[17]. The risk is related to, first, the uncertainty of the success of the movement in satisfying the initial need and, second, to the hazards of movement such as accidents.

Within ITS, measures that aim to directly influence user behavior need to be distinguished from systems the user chooses to utilize or not to use. The former are in many cases applied by authorities or operators of infrastructure and aim at controlling transportation system users through mandatory instructions. The latter are either individual systems which users activate or systems addressing the collective where transportation system users can choose to exploit the information provided. In any case, a user choice determines whether the ITS becomes effective or not. This choice, marked as "Choice I" depends on the characteristics of the system and the characteristics of the user, as detailed in Figure 2. Whereas the situation of user choice is clear regarding non-mandatory systems, it is important to not assume blind adherence to any rule. For the case of variable speed limits, a study showed significant disrespect regarding the displayed maximum speed. Low mandatory speed limits on highways were disregarded by about 70% of users (Rechnungshof 2009, p.175). The effectiveness of the variable message sign is in that respect very low. The ASFINAG described experiences whereupon adherence increases if additional information about the reason for the lowered speed limit is displayed simultaneously. Further suggestions include increased control of adherence to rules. This measure is deemed to have the most significant impact on variable message sign effectiveness (ibid.). Stevens (2004, p.92) also remarks on the increases of efficiency when multiple ITS are combined.

If the user decides that he will not respect or use ITS systems, then the choice regarding the behavior in the transportation system will be unchanged. This is an assumption valid for a single situation. Should the situation change, e.g. user preferences or the system characteristics of ITS become more attractive, a different result is possible; in future developments this may very well be the case.

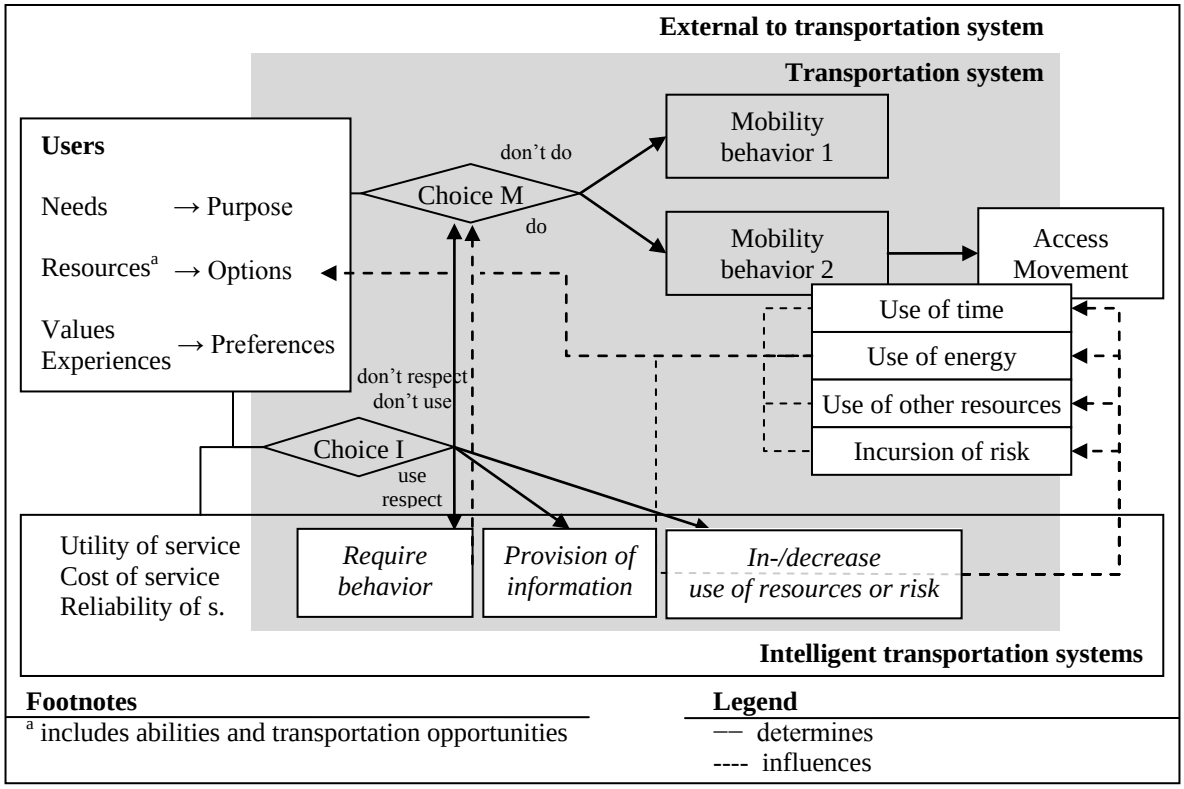
In case the user chooses to respect ITS requiring a certain mobility behavior[18] (Choice I), this will directly affect the choice of behavior in the transportation system (Choice M); see Figure 2. Many

[17] This risk associated with the usage of the transportation system is not the same as the risk in implementation of ITS.

[18] Examples are dynamic speed limits or ramp meters.

ITS applications provide information, e.g. on routes, system state, costs, etc. They affect the perception of the individual's options and, at the same time, the effort of planning prior to or during the use of the transportation system. Finally, a variety of ITS directly affect the amount of resources a user has to devote to movement. This also affects the options of the user and thus possibly the choice of mobility behaviors could be changed. All increase or decrease the ease of access to a certain location in a certain traffic mode. If there are alternative modes, the relative attraction of one mode to the user may change if an ITS system is implemented. Thus ITS may be able to induce modal changes.

Figure 2: User choices in an ITS enhanced transportation system



Source: Author

Further issues that occur in context of ITS and influence the acceptance or utilization of an application are issues of privacy and issues of legal responsibility in case of system failures.

Since most ITS either include surveillance components as part of their functions or allow reconstruction of mobility patterns of persons, the protection of privacy is an issue. A full review of the debate on this issue would be too extensive to be included in this thesis since contemplations on the right to privacy and data protection would need to be addressed. Independent of the legal situation regarding data protection, individuals may forgo utilization of an ITS if they fear their privacy could be compromised. Equally, institutional users might be concerned about the revelation of trade secrets e.g. how commercial vehicle operators or public transit operators conduct their business (Janello & Bruns 2005, p.11). This determinant of usage may significantly influence usage and consequently the effects generated by an ITS and thus is a relevant issue in evaluations.

Lack of regulation concerning responsibility in case of ITS failures is also a strong inhibitor of deployment and even to development. Practical examples are the discussion on autonomously

driving cars or platooning[19]. To date it has not been determined who is responsible for casualties and damage caused by accidents resulting from the failure of such ITS. Since both developers and users are adverse to this legal risk, application of ITS containing it will necessarily lag.

ITS Effects on Equity

To find out whether an ITS will be accepted, the items "cost" and "ability to operate ITS" have been identified. In addition to their critical importance in the context of the aforementioned issue, they are not neutral regarding the equity of access which is discussed as follows.

For ITS functions that qualify as private goods, charges may be put in place. In other cases, ITS users must be able to afford the necessary equipment and data transfers to exploit ITS. Poor people might not be able to afford these costs. Thus they are excluded from the benefits. In some cases, this may be ethically debatable, for example if a poor person incurs greater risk of having an accident when travelling by car than a rich person in a vehicle equipped with various ITS safety applications.

Another probable scenario is that, while people with sufficient wealth may be able to use ITS to save resources, for poor people the cost of transportation remains the same if they cannot access ITS. Compared in relation to the ITS users, poor people's situation worsens. Additionally, it might be the case that the costs of using the transportation system in a conventional way increase in absolute terms if ITS systems are introduced.[20] Operators may hope to refinance an ITS that way and at the same time provide an incentive to use the ITS. Poor people might have to expend more resources for movement or trip planning if they cannot access ITS. In the light of scarcity of resources inherent to poverty, the problem becomes clear. It leaves poor people with fewer opportunities to autonomously emerge from poverty.

Aside from economic equity, an even more frequent issue than the exclusion of poor people may be the exclusion of people with little or no abilities to operate electronic devices. Especially regarding individual ITS functionalities, it is mostly necessary to control and understand the outputs of user interfaces. Persons without these abilities are automatically excluded from using and benefiting from ITS. Even in a highly developed country as Austria, a 2009 survey found that only 70% of households had internet access. Of the 75% of the population which used computers, 16% have very limited ICT competency (STATISTIK AUSTRIA 2010a, pp.21-25). Hence, these problems regarding the accessibility to ITS are currently[21] an issue for a large part of the population.

For both poor individuals and persons without the necessary ICT competence, the intensity of exclusion increases when ITS begin to replace commonly accessible conventional services. An

[19] Platoning refers to the connection of cars or trucks to trains. Vehicles in the train are guided by the first vehicle. Spacing between vehicles may be reduced significantly and drivers of non leading vehicles are free for other activities.

[20] En example may be extra service charges for not purchasing a ticket/paying a fare electronically.

[21] Not surprisingly, older age groups have less ICT competence than young people. Equally, while 97% of people between 16 and 24 years of age use the internet, only 21% of people between 65 and 74 declared doing so. In addition to a steady increase of internet availability in households, which doubled between 2002 and 2009, demographic progression will increase the share of ICT competent persons with access to the internet over time.

example taken from public transport is the reduction of personnel able to provide information. Also, poverty and lack of ICT competence may correlate to a certain extent, increasing the barrier for the individuals in question.

Finally, as ITS generate external benefits, some of the disadvantages due to inequality of access to ITS may be set off. For example, ITS users invest in additional components to access route guidance information. Thus congestion is reduced by the amount of vehicles able to avoid the roads used above capacity. Non ITS users on the formerly congested links will benefit largely since they did not incur any cost, neither for the ITS nor for evading the potential congestion, and still travel quicker.

Regardless of which equity issues occur, their magnitude and the groups of persons impacted will largely depend on the type of ITS. Variations on details of how the system is set up may have significant consequences in this context.

Mitigation of benefits through adaptation of user behavior

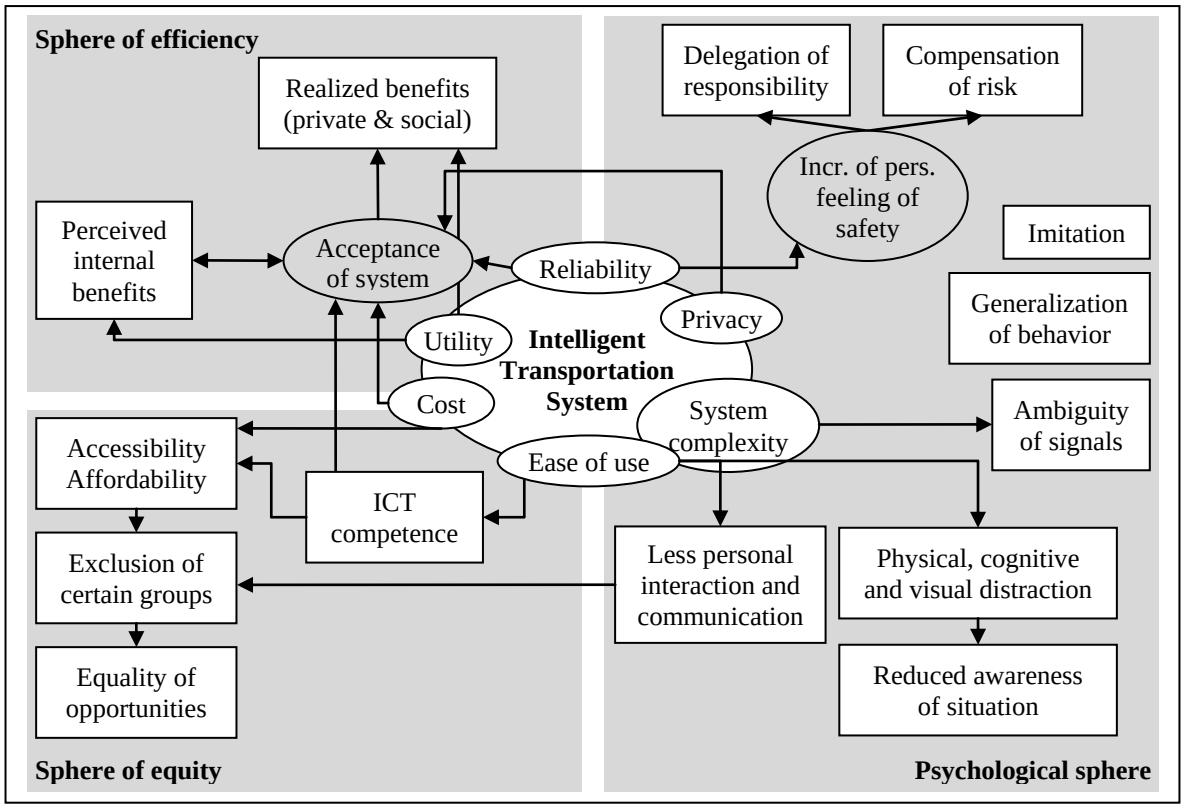
Psychological effects of ITS occurring with transportation system users may lead to undesirable behavioral responses of these users. The benefits of the measure may be mitigated or even overcompensated. Ausserer et al. (2006, p.42) list six issues:

- Compensation of risk – Users become less careful in situations they perceive as safe.
- Delegation of responsibility – Aside from not perceiving the severity of their actions, users may unlearn important reactions because they are increasingly assumed by machines.
- Imitation – Users with non-ITS outfitted vehicles may imitate machine controlled driving behavior and be overwhelmed by the situation.
- Ambiguity of signals – Due to increase of system complexity, signals in the transportation system become more difficult to comprehend and could be misinterpreted.
- Generalization of behavior – Users may carry on in the behavior mode supported by ITS although the functionality is not available in other situations.
- Reduction of interpersonal communication – Users of ITS may rely heavily on the technological support and neglect to look for signals of other transportation system users.

Additionally, some ITS may distract drivers' attention from traffic which constitutes a safety risk. Especially on-trip navigation leads to reduced awareness. The driver can be distracted physically, cognitively or visually (Ausserer et al. 2006, p.47). This may lead to increased risk of accidents. However, such disadvantages could be avoided by additional ITS assuring safe vehicle guidance. Again, various ITS may harmonize well leading to increased the positive effects

Mainly the problems with unintended behavioral adaptations occur in the mode of motorized road traffic. This of course includes professional drivers as well. The impact of ITS in public transportation passengers generally bears less potential for dangerous behavior. There, issues are related especially with user acceptance (Ausserer et al. 2006, pp.56-58) and exclusion due to lack of ICT knowledge.

Figure 3: ITS characteristics and aspects of economics and social sciences



Source: Author, modified based on Ausserer et al. 2006, fig.1

The issues of user acceptance, equity and unintended behavioral adaptations and identified interrelations described so far are illustrated in Figure 3. Next to issues of costs and utility, in particular the reliability and the ease of use of an ITS are determining factors for its success. Acceptance of the system by users is especially significant in order to consequently determine the benefits actually realized. Prediction or measurement of utilization have to be especially sensitive in the case of ITS. Changes in utilization over time periods may be linked to the complicated process of acceptance.

2.2 Identification of involved parties

The process of establishing an ITS involves many different parties. A detailed list of stakeholders has to be compiled for each project specifically. In evaluation, this list becomes especially important when analyzing the distributional consequences. Professionals usually develop, as a by-product of their activities, knowledge about the relevant stakeholders. To identify stakeholders as a first step in analysis, the suggested approaches seem rather commonplace as summed up by Jepsen & Eskerod (2009, p.337): brainstorming or conducting interviews; Brook-Carter (2002, p.24) using a more technical terminology refers to expert panels. Another option is the use of generic lists. Pouloudi & Whitley (1997, p.4) argue that these are not appropriate for all contexts. The following section establishes such a generic list for ITS projects, but a note of caution must be sounded because the details have to be adapted to a given project.

2.2.1 Classifications of involved parties

A common differentiation of stakeholders is based on their economic interests and their situation in respect to functions they assume in the society. The following list states four categories of transactors.

- Private households,
- Profit oriented enterprises,
- Public agencies,
- Non-profit organizations.

A categorization based on these principals is used by Turner & Stockton (1999, p.12) for their evaluation of an ITS framework for the State of Texas. The modifications are related to the inclusion of categories for users and non-users. For the evaluation of transportation systems, or ITS for that matter, it is often necessary to classify stakeholders based on their relation to the analyzed system(s). The following categorization is therefore based on the functional roles of stakeholders.

- Actors establishing policy and the regulatory framework
- Operators of ITS
- Providers of ITS components and IT services
- ITS users
- Unintentionally affected

Actors establishing policy and the regulatory framework

The process of policymaking is complicated and varies greatly. Usually a policy reflects a set of common values. Often it is related to the cultural heritage and influenced by certain interest groups or scientific insights. Policies are often stated in strategic documents where issues which could be commonly agreed upon are recorded. These documents may be used to guide further action. Public agencies establish the necessary regulatory framework for public and private actions according to the policy and the regulatory heritage. ITS projects are developed within this framework of regulation and strategic goals. They receive final approval from public and/or private decision makers. Public agencies often further support development by funding research or implementation projects. Especially with ITS, where emerging technologies are applied, such programs provide important incentives. Evaluation of these subsidy programs is not within the scope of this thesis. However, the subsidies themselves have to be accounted for when analyzing a project. First, in case of limitation of analyses to certain agents, the perceived cost of an ITS project could change due to income from direct transfers or use of subsidized inputs. In addition, the interests of the subsidizing agency might influence the conception of the project.

Operators of ITS

Organizations operating transportation infrastructure and offering transportation services are in many cases also operators of ITS, for example in traveler information or demand management, but also maintenance -, or emergency response management.[22]

A first example of stakeholders in this area consists of private companies or public agencies maintaining road or rail infrastructures. As the past decades have seen waves of restructuring in Europe, many important operators are now publicly owned but privately organized companies. The non-high level road network and infrastructures serving non-motorized traffic is, in general administered by territorial authorities at the provincial and municipal levels. Car park operators' organizational structures are heterogeneous and may include privately owned companies.

Providers of transportation services intensely apply ITS for fleet management or customer information. Transport associations coordinating transit service provision also shall be named in this category. In addition to the public institutions in public transportation, many bussing companies are actually privately owned. In logistics, most trucking companies are privately owned. Freight service on rail is dominated by public enterprises. The increasing dynamics of transportation service provision leads to various other products such as car sharing or public bicycles. Due to the heterogeneity of the institutions providing these services, a general statement on their nature is not possible.

It is also conceivable that ITS are operated by institutions not involved in any other way with the provision of transportation capacities. Such businesses can include navigational or other transportation related value added services. In some cases, mobile communications companies or broadcasting systems become active in this area. Alternatively, it is not said that a private company cannot provide such services as its core business.

Finally, it is also possible that bodies of executive road enforcement or rescue organizations operate ITS.

Providers of ITS components and ICT services

As ITS introduce a lot of electronic devices and data processing software to the transportation system, companies providing such equipment and services become involved two ways. They contribute to the process of research and development and, on the other hand, face increased demand for their products by operators and users of ITS. Opportunities are not only available for large high-tech industry companies. Very small enterprises can also be successful.

The vehicle industry is also strongly involved in the process of ITS development. ICT components are increasingly being integrated into vehicles. Thus the vehicle industry plays a key role in making ITS services accessible.

Some ITS applications, e.g. traveler information, require data transfer via the internet or to mobile devices. This service may be supplied by the existing internet providers and mobile network

[22] In the latter two cases, operators take on a double role as they are the users and operators of a system at the same time.

companies. Revenues may rise due to increased usage of these resources. For some users, individual traveler information may even be one of the key arguments to buy contracts allowing extended data transfer.

The organizations named so far are exclusively private enterprises. However, further inputs for ITS functions may also be provided by public institutions. Weather data providers, for example, are often maintained by public funds

Users

Users are those stakeholders exploiting ITS services to gain certain benefit, or those who are subjected to behavioral changes required by ITS. Any user of a transportation system is a potential ITS user as well. Further differentiation is necessary between individuals and organizations. Individuals use ITS to plan a trip or while on a trip. Commonly, they do not operate ITS[23] in the sense of maintaining ITS components but only access the functions.

In some cases, institutional users may be both operators and users of ITS. Infrastructure operators, transportation service enterprises, logistics companies, etc. which operate ITS for their own benefit also have to be listed as users, to consequently follow the established definition.

Unintentionally affected

Individuals, groups or institutions which suffer or enjoy the external effects of ITS measures are classified as unintentionally affected. In some cases, they will be organized and become an important party in the decision making process, but it is equally possible that they are not aware of the cause of their suffering or advantages. The latter may often be the case regarding ITS projects. First, effects may be small and irregular and therefore difficult to notice. Second, ITS measures often do not involve extensive construction work at the locations where effects appear, so the moment of activations my go unnoticed. A similar problem is that the effects are related through the transportation system, such as changes in traffic intensities, and hence the transportation system is identified as the cause instead of the ITS. Third, the concept of ITS is not known as such in public. Even though users may become increasingly aware of ITS functionalities they can access, the complexity of the system as a whole will generally not be understood. As a consequence of the second and third issue, tracing an effect back to an ITS may be difficult for unintentionally affected parties. With major construction projects, a certain interest on the part of the affected may be assumed. However, an analysis of ITS stakeholders has to be especially sensitive in identifying unintentionally affected since they might not be presenting themselves.

Further, territorial authorities may sometimes be unintentionally affected. ITS projects may produce shifts in tax revenues. In cases where the territorial authority is not involved in the ITS project, it may be assumed that both positive or negative impacts on the public agency are not related to the core objectives of the project and, as such, are unintentional. Further, if even one territorial authority is involved in an ITS project, other territorial authorities on other levels or at the same hierarchical level (e.g. in case of provinces, municipalities) may be affected.

[23] Except for user owned user interface devices (in case such are necessary) and vehicle based ITS in private cars.

2.2.2 References to stakeholders related to ITS measures in Austria

Depending on the category at hand, the numbers and characteristics of stakeholders in Austria vary greatly. Where large numbers of stakeholders appear, and a disaggregation to individual examples is not sensibly possible due to the limitations of available space, the description of the stakeholder groups in the previous subsection 2.2.1 may be used as a point of departure to determine the stakeholders relevant to a specific project. This is especially the case for the stakeholder categories of users and unintentionally affected, which are not repeated below. More details may be provided for operators and providers of ITS components and IT services. Examples are provided in the table in Annex 1.

Actors establishing policy and the regulatory framework

The policy making process and establishment of a regulatory framework regarding ITS is, to a large extent, borne on the national level, but the provinces also make contributions. However, certain values and regulations are already established at the level of the EU. As the executive body, the EC has an important role in this process. Several of the EC's Directorates-General are involved in ITS program planning (EC 2008b, p.8). While incentives for cooperation and international standards directly address issues of ITS development, regulations on competition such as restrictions regarding national subsidies also have to be respected. Funding for development programs was mainly provided by the Directorate-General for Mobility and Transport (DG MOVE)[24] and the Directorate-General for Information Society and Media (DG INFSO). Austria, as part of the EU, is directly subject to developments on that level.

Nationally, the territorial authorities bear important responsibilities. At the federal level, the Federal Ministry for Transport, Innovation and Technology (BMVIT) is the most important actor in relation to ITS. Not only is it involved in major infrastructure development including planning and financing, but telecommunications and innovation management also lie within its authority (BMVIT 2010). As explained in Chapter 1, ITS measures are situated exactly within the intersection of these fields. Further, provincial governments, through their transportation planning departments, play a role. In some cases they provide co-financing of systems[25] or come to systemic decisions for the implementation of ITS[26].

Operators of ITS

A large variety of stakeholders appear as operators. A prominent position may be attributed to the Austrian federal railway (ÖBB) and the Federal freeway management agency (ASFINAG) which are recurrently listed as actors or stakeholders in the section describing measures proposed by the Austrian telematics framework plan (Pfliegl et al. 2004).

To gain an overview of organizations in public transit, many of the transport associations provide information on the services and organizations within their area. A list of transportation associations

[24] Formerly DG TREN until Feb 2010

[25] For example, in the case of the AVL/dynamic traveler information implemented by the Graz AG Verkehrsbetriebe. (Amt der Steiermärkischen Landesregierung, Referat Öffentlicher Personenverkehr 2010)

[26] Sponsorship of a system evaluation by Janello & Bruns (2005) by the provincial government of Tyrol.

which cover the whole Austrian territory is available on the website of the BMVIT[27]. An interest group such as the Association of German Transport Companies (VDV) or the Swiss counterpart VÖV does not exist in Austria. Enterprises incorporated under civil law and in business with road transportation are associated in different groups of the Austrian Federal Economic Chamber (WKÖ)[28].

Providers of ITS components and IT services

An idea of some of the larger organizations and companies involved in the development and provision of ITS in Austria can be gained from the website of the Austrian Traffic Telematics Cluster (ATTC)[29]. However, small enterprises are not listed. A more comprehensive overview of the active stakeholders in research and development can be derived from submissions within the BMVIT's Strategy Program on Mobility and Transport Technologies for Austria. Reviews of the successful applications are available at the BMVIT's website[30].

2.3 Identification and categorization of effects

2.3.1 Approaches to identify project related effects

An essential step in any project evaluation is the identification of effects. If relevant effects are overlooked, the result of the evaluation is practically useless.[31] The process of identifying effects is, in any case, challenging, especially due to the complex interrelations of the transportation system which is affected by ITS functionalities.

The initial step to identify the relevant effect will always be a detailed description of the project to be evaluated. This includes an account of conditions and factors which are able to significantly influence the magnitude of the effects produced. In the case of ITS projects, the subsections 2.1.3 and 2.1.4 provide substantial information regarding such conditions and factors. As ITS include a very large variety of technical measures, some projects may require a more detailed description of one or another specific issue which was not mentioned here. Once the detailed project description is complete, this already provides a solid basis for identification of many of the project's effects.

There is no uniquely correct manner whereby a list of effects is compiled. However, certain concepts are recurrently suggested for use. A structured approach will, in any case, guarantee the best possible result, as it aims to avoid the overlooking of effects. The following process of four steps is suggested.

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[27] http://www.bmvit.gv.at/verkehr/nahverkehr/verbuende/oesterreich.html - Accessed June 17, 2010

[28] Sectoral groups of the WKÖ are, for example, the
- Association of bussing entrepreneurs (http://www.fachverband-bus.at/ - Accessed June 17, 2010),
- Association of cargo haulers (http://www.dietransporteure.at/ - Accessed June 17, 2010),
- Association of taxi drivers (http://www.fachverband-taxi.at/ - Accessed June 17, 2010)

[29] http://www.attc.at/index.php?id=attc-mitglieder - Accessed June 17, 2010

[30] See for example:
http://www.bmvit.gv.at/innovation/verkehrstechnologie/downloads/i2v_ergebnisse2.pdf
http://www.bmvit.gv.at/innovation/verkehrstechnologie/ways2go/ausschreibung2.html
both - Accessed June 17, 2010

[31] A more differentiated view is necessary when identified effects perceived as significant cannot be incorporated due to resource constraints for the evaluation. However this issue is not of primary concern in the initial process.

1| The operator's costs of implementation and operation of a project provide a solid point of departure. Based on the project calculation, a detailed accounting of effects within the stakeholder's financial balances is possible. In the light of a prospective social or environmental evaluation, these costs should also be expressed in terms of resources consumed. A guideline on how to identify and collect cost data for ITS was issued by the RITA (1999). An example of a cost survey can be found as part of an assessment of the potential of ITS applications for busses in public transit (Janello & Bruns 2005, pp.31-33).

2| A representation of project goals helps to identify all areas where intended effects appear. An example of such an arrangement is given in Figure 4.

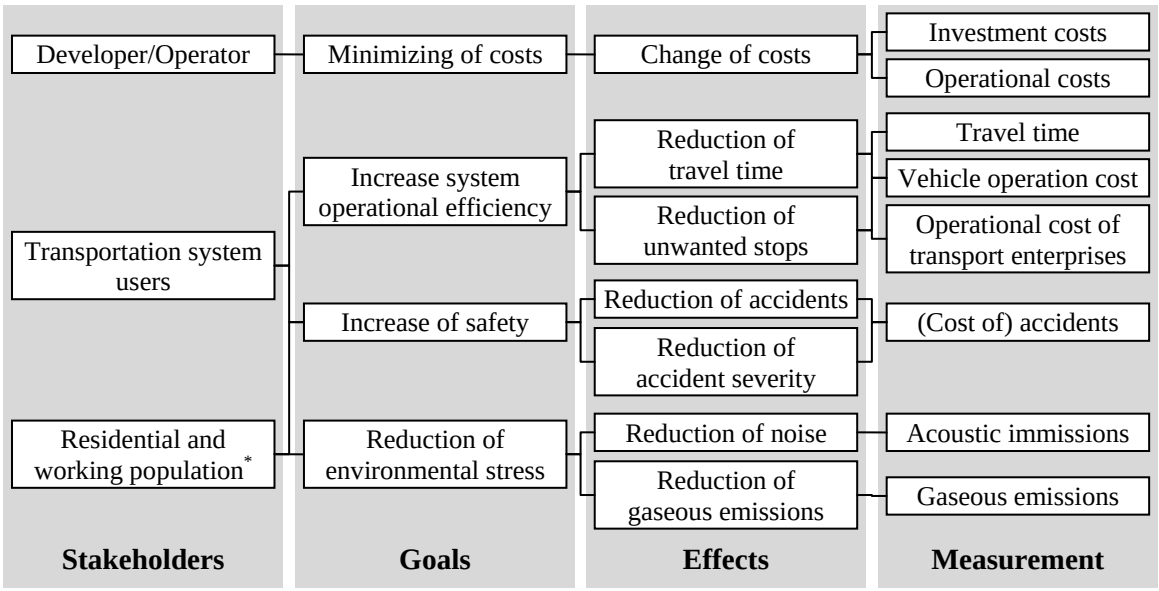
3| Further effects beyond the narrow project specific goals may often be revealed if the project is viewed in the context of other objectives. These alternatives may be derived from public policy areas, or directly by consulting stakeholders or interpreting their preferences. Peng & Beimborn (2000, pp.5-7) also described the value of this approach and provide three exemplary benefit trees for the ITS applications of traveler information systems, incident management systems and commercial vehicle operation systems.

4| Finally, effects that have so far not appeared may be identified by tracing causal relationships. This technique is especially needed to discover non-anthropocentric effects, should that be necessary. Project, stakeholder and policy goals, the foundations of the steps described so far, are predominantly, maybe even exclusively, oriented to the needs of humans. The systemic tracing is certainly a task that requires a significant amount of time, especially if the system representations have to be constructed first. Figure 5 presents an example of a system diagram. Although it mainly focuses on the environmental aspect and thus neglects detailed treatment of various other systems, the complexity arising from system inherent causal loops is perceivable.

In addition to a structured approach to identify the effects of a project, generic lists may be of help. Such a listing of examples is available for ITS cost items (RITA 1999, pp.17-22). A set of measurement indicators structured by various goals is provided by Turner & Stockton (1999, pp.15-20). Effects that occur in generic lists or appear recurrently are discussed in 2.3.3. As previously mentioned in section 2.2 in the context of stakeholder analysis, it is equally if not even more important to adapt and, if necessary, to extend generic lists in the context of effect identification.

Although, the major issues are likely to be identified in the four step process, it may still not reveal the full complexity of a project's effects; even if systemic tracing is applied. Construction of system representations is, to a certain extent, arbitrary, and the involvedness of the real world can probably never be accurately described.

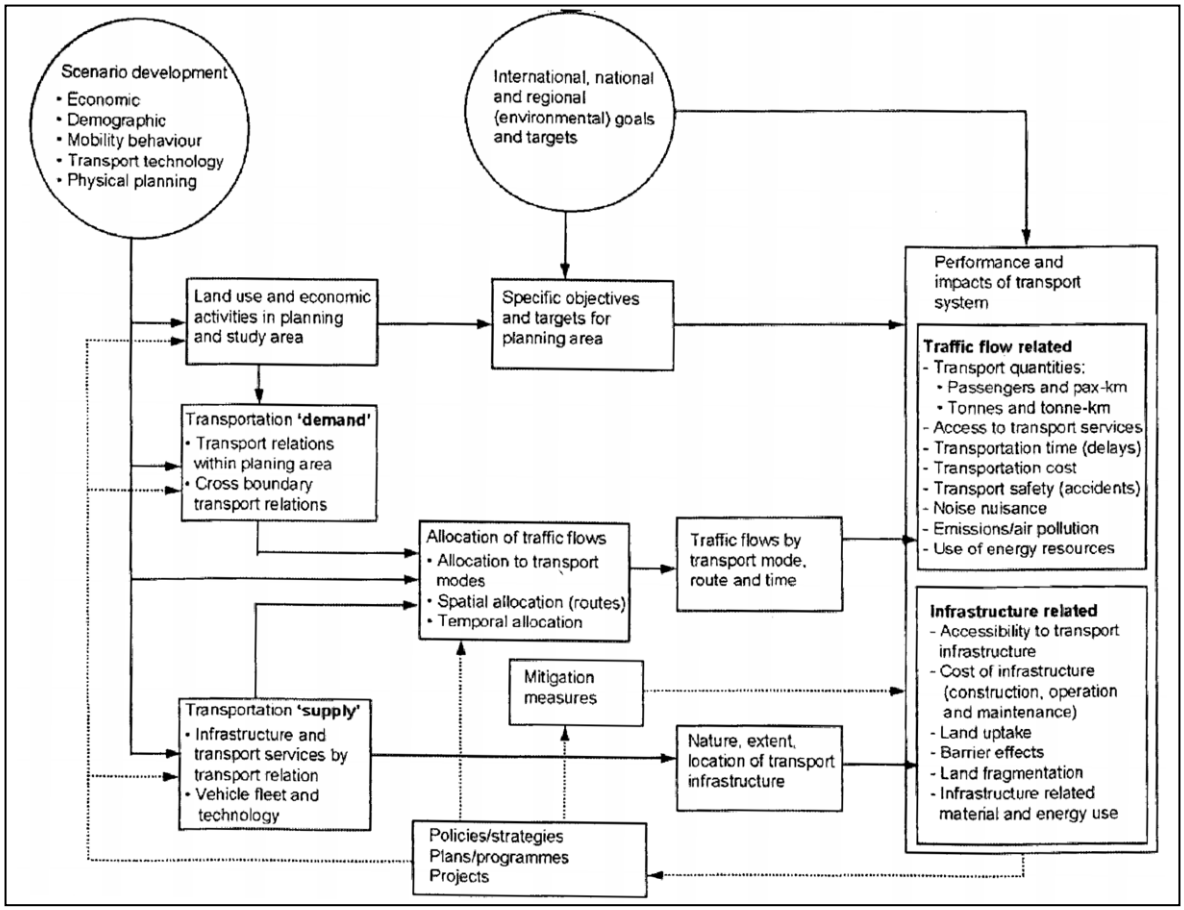
Figure 4: Example of a schematic of goals and effects for an ITS project



* Inclusion for depending on project or interest of the evaluation

Source: Author; based on FGSV 1988, p.8, Figure 2; Hampe et al. 1981, p.3, Figure 22.2

Figure 5: System diagram for assessment of traffic and infrastructure impacts on a strategic level



Source: Zotter et al. 2009, p.93, Figure 2.2

2.3.2 Classification and selection of effects

Often a large number of effects can be identified for a given project. Only a certain number of these will finally be incorporated into the evaluation. Hence selection is necessary. Three issues are especially relevant for the selection of relevant effects. Those are:

- Scope of the evaluation – effects outside the scope of the evaluation are neglected.
- Reference case and project alternatives to be evaluated.
- Evaluation method – Depending on the objective of the evaluation, or in case an evaluation method has already been determined[32], not all of the four steps described in 2.3.1 will be executed. It was found that the approach to identify a project's effects is often related to the evaluation method that shall consequently be applied. For evaluation methods such as CBA, CEA or MOA, a system of hierarchical goals is established whereupon the effects may be determined (FGSV 1988, p.8f.; Hampe et al. 1981, pp.2-6). This correlates with the steps two and three described above. Environmental analyses tend to resort to systemic analysis, as described in the fourth step, where the cause is located in the analyzed system and effects are traced following the causal relationships (Smeets & Weterings 1999, p.6).

To adequately perform the selection of effects, describing them in a structured way through classification is helpful. This makes it possible to gain an overview. Based on the systematic description of the effects, they can be discarded as unfit for a certain evaluation method[33] or have to be eliminated as irrelevant to the specific scope. The categories refer to different aspects of an effect and are not mutually exclusive.

Regarding the operational treatment of effects in evaluations, the following differentiations can be made:

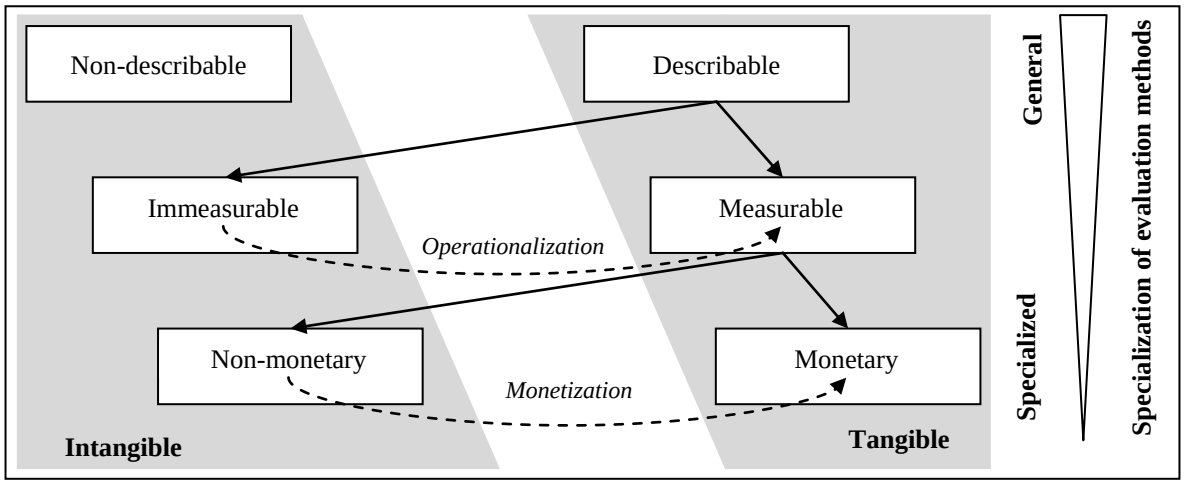
- System-internal or system-external: "System" here refers to the scope of the analysis. Effects that are system external in terms of spatial or temporal occurrence are not taken into account in the evaluation. Determining whether an effect lies within or outside the scope means to determine whether it should be integrated in the evaluation.
- Tangible or intangible on the other hand are used to define which effects can be incorporated in the analysis. Tangibility is to be defined relative to the evaluation method. Depending on the method used, the criteria defining the tangibility are more or less restrictive. Hence, an effect determined tangible in the context of one evaluation is not necessarily tangible when applying another method. Mainly three characteristics of an effect which are listed below will determine the effect's tangibility; Figure 6 illustrates the concept.
    - The effect may be describable or not. If it is not possible to describe the effect in any way, it is impossible to incorporate it in any project evaluation, even if it is a qualitative approach. This also includes effects the magnitude of which is so small that they cannot be detected but which otherwise would qualify as measurable.

[32] In some cases the objective of the evaluation, as defined by the stakeholder commissioning it, may leave little room for methodological choice. See 3.1.2 for further details.

[33] In the interest of transparency, effects that have to be neglected for this reason should at least be listed and, if possible, discussed verbally as part of the evaluation.

- Measurable and immeasurable: Quantitative evaluation methods rely on measurable effects. Measurability in a strict sense is closely related to the quantification of physical effect. The effect is usually measured in its unit of measurement. ITS projects, and projects in transportation in general, generate many non-physical effects as they are realized in socio technical systems. It is more difficult to define measurability in the non-physical area. Here, it is assumed that all effects which may be quantifiable in an established system of measurement are measurable in a wider sense. Especially in social sciences, proxies often have to be applied to measure an effect or scale transformations are used. These practices are part of operationalization techniques. Effects measured through operationalization may be viewed as measurable in the broadest sense. Operationalization is usually prone to critique and debated in scientific practice. However, it is commonplace in various project evaluation processes, especially in MOA, (see 3.2.6). Thus, an effect initially classified as immeasurable does not necessarily remain excluded from all quantitative evaluation methods. The progress of science, especially in the areas of natural sciences, psychology and economy, constantly contributes techniques to operationalize previously immeasurable effects.
- Monetary versus non-monetary: The monetary system is a specialized measurement system. Thus, immeasurable effects are necessarily non-monetary. While the monetary system is the natural measurement unit, it is also used for many intrinsically non-monetary effects. Often, if market transactions occur regarding certain effects, they are both measurable on a physical scale and on a monetary scale. The monetary scale is a foundation of most economic evaluation methods. As the economic project evaluation methods have an important role in evaluation, the choice will often be to use monetary measurements directly. In some cases, monetary values will have to be corrected for distortions. Non-monetary effects have an important role in some overall social and especially in environmental evaluations. Just as there are procedures to integrate immeasurable effects in evaluations, techniques to make non-monetary effects measurable in monetary terms have also been developed. These monetization techniques are contemplated in the context of CBA.

Figure 6: Determinants of tangibility in the light of specialization of evaluation methods



Source: Author

A second set of categories describes the occurrence of effects:

- Direct as opposed to indirect describes whether an effect is intentional (direct) or not (indirect). This definition by Schönbäck et al. (1997, p.5) views intentional effects as those occurring to the project developer, the operator, users and cost bearers involved. Unintentional effects are those occurring to agents otherwise not involved. A further common explanation is that direct effects are closely associated with a project's main goals and indirect effects are by products (R. A. Musgrave et al. 1994, p.191). This is a practical definition when faced with one or very few goals. In case of analysis regarding a great variety of goals, it is less appropriate because then the number of effects that would have to be classified as direct grows accordingly. Consequently, the distinction becomes redundant to a certain extent. Hence, the use of a narrow set of project specific goals (e.g. those associated with operators and users) to classify direct and indirect effects is suggested. Direct effects may be identified following the techniques proposed in the first end second enumerated items under 2.3.1. The third and fourth more likely produce indirect effects. Following this definition, R. A. Musgrave et al. (ibid.) further define primary as direct and secondary as indirect. This will not be adopted here since primary and secondary are used for a different purpose.
- Usage related effects are self-explanatory. The counterpart, non-usage related effects, may include effects that are derived from the option to use a project or good, the mere existence of a project or good although there is no way to make use of it, and the value of conservation of a good or quality.
- Primary as opposed to secondary describes whether the effect is an immediate consequence of the project or if it occurs as a consequence of an immediate effect, as part of an impact chain. This definition finds a clear application in the AVA (see subsection 3.2.3). In other cases, it is a lot more difficult to determine which effects are immediate and consequently which others are secondary. Especially in ITS, a solution has to be found since most immediate effects induce changes within the transportation system only and thus all other resulting effects derived from these changes should be designated secondary. A secondary effect is not less important than a primary effect. The differentiation between primary and secondary effects may be helpful in identifying issues of double counting.

Third, a set of categories is dedicated to the economic description of effects:

- Internal and external effects have already been defined in subsection 2.1.4. To complete the overview here, it shall only be said that internal effects are those which appear in the project developer's/operator's accounts. External effects are all other.
- Real as opposed to pecuniary: Real effects are changes in the utility of private households (individuals) as a consequence of changes in productive capacity or availability of resources. Only real effects can reflect increases in social welfare. Pecuniary effects on the other hand are changes in relative prices which follow a shift in demand from one good to another. Any purely redistributive transaction is also a pecuniary effect. (R. A. Musgrave et al. 1994, p.189; Schönbäck et al. 1997, p.4)
- Intermediate as opposed to final effects: Changed availability of final goods to consumers produces final effects. Intermediate effects are changes of goods that are only used in the productive process. Depending on the point of view, one good is a final good for one agent

and an intermediate good for another. (R. A. Musgrave et al. 1994, p.192) The point of view is defined by the categorization of an agent in the national accounts.

To provide an overview, the above described options for categorization are listed in Table 2.Some classifications appear similar at first sight. However the more intensely the categorization is contemplated, the more the subtle variations become clear. As a matter of fact, not every evaluation method requires project effects to be categorized by the full spectrum.

Table 2: Summary of categorization pairs

Group	*Categorization pair*	
operational	system-internal	system-external
	tangible	intangible
occurrence	direct	indirect
	usage related	non-usage related
	primary	secondary
economic	internal	external
	real	pecuniary
	intermediate	final

Source: Author

Some authors limit themselves to a classification with far fewer categories. G. Weisbrod et al. (2009, p.333) for example use: direct, indirect, other societal concerns. A classification focusing more on the sectoral appearance of the effects is used by Bristow & Nellthorp (2000, p.53): direct, environmental, economic. This simpler approach may be sufficient but it appears the cited authors only use the categories for grouping the effects in the evaluation. A more detailed description is recommended, especially when faced with a selection process.

2.3.3 Effects recurrently incorporated in ITS evaluations

The description of ITS so far has shown that certain effects are equally generated by various different ITS applications. Also, some effects may be described as essential to evaluations in transportation as they occur independently of the specific form of the project, e.g. with infrastructure construction as well as with regulatory measures or ITS. In pre-tests which were conducted as part of the FTIP in Germany for about 100 road construction projects, the most relevant positive benefit categories were the reduction of transport cost, accessibility effects and traffic safety effects (BMVBW 2002, p.9).[34] Equally, many ITS projects show significant strengths in these areas, especially regarding transportation cost and safety issues.

On the other hand, some effects appear to be related more exclusively with ITS. Examples here are reductions of operational costs of infrastructure and vehicles, reliability of transportation services and, partially but not necessarily associated, changes in customer satisfaction with existing

[34] Environmental factors such as out of town noise or greenhouse gas impacts as well as intermodal shifts and induced traffic would only reduce benefits by about 20%. Some particular cases though, demonstrated higher sensitivity in these areas.

transportation services. In practice, isolation of ITS effects is difficult because of the integration with the transportation system and complex synergies between public policies (Stevens 2004, p.104). In their analysis of evaluation methods for ITS, Leviakangas & Lahesmaa (2002, pp.278-279) directed some attention to generalizing differences between ITS investment projects and what they refer to as conventional physical infrastructure development projects. Table 3 presents their findings regarding project costs of ITS and conventional projects for road traffic. The notions are certainly valuable in the process of orientation but at the same time, any such generalization is prone to criticism. Different scales of projects may cause variations of the figures that are by far greater than the table demonstrates. Further, these results focus on road transportation. The magnitude and occurrence of the effects may vary greatly in other modes of transportation.

Table 3: Selected differences between ITS and constructional road expansion projects

Costs	*ITS investment*	*Physical infrastructure investment*
Investment cost	Relatively small (e.g., 2-4 million euros)	Usually high (e.g., 100-200 million euros)
Life time	Short/Medium (e.g., 5-10 years)	Long (e.g., 30-50 years)
Salvage value after full depreciation	Usually no value	Significant value (e.g., 20% of investment cost)
Operating costs of the system	Significant to total cost	No operating costs (or at least these costs are insignificant)
Effect on other costs of the road authority	Sometimes indirect effects, for example on the efficiency of winter maintenance	Usually direct effects, for example, on repair and maintenance costs
User Costs	Accident and time costs often cancel each other out	Usually all user costs decrease

Source: Leviakangas & Lahesmaa 2002, p.278 Table 1 (format adapted)

In 1996, the FHWA developed a set of six criteria specifically for ITS that were found to cover the most relevant effects while at the same time, techniques of measurement or operationalization existed and the measures were accepted by stakeholders. The effects to be analyzed, derived from the policy goals set for ITS developments, are *"Crashes, Fatalities, Travel Time, Throughput, User Satisfaction or User Acceptance and Cost"* which are since termed the *"few good measures"* (FHWA 1997, p.4). These criteria consequently form the core of most evaluations conducted in the US. An adapted version of these criteria is published on the RITA website on evaluation guidelines, as summarized in Table 4. A similarly frequently cited suggestion from European bodies could not be found, however that does not imply that guidance does not exist. Probably one of the most detailed documents directly aimed at ITS evaluation was produced within the Finnish program of research and development. Although the list seems somewhat more extensive, the core issues are similar. The effects are denominated: "network and its cost", "fleet and its cost", "accessibility", "time and its predictability", "traffic safety", "noise emissions and energy" and "valuations and comfort" (FITS 2002, pp.28-38). Indicators, distinguished according to their importance, are specified to measure each of the effects. Further, a method of measurement is proposed or data sources listed.

The cited guidelines cover a broad spectrum of ITS effects and also demonstrate the difficulty of measurements, predictions and acceptance. Empirical research conducted by Newman-Askins et al. (2003, p.11) on ITS evaluations in Australia revealed a set of frequently considered ITS effects, (see Table 5), that parallel the FHWA's suggestions. It may be the case that the generic lists provided in guidelines strongly influence the choice of evaluation criteria and thus explain the notable overlapping between the suggestions. The empirical evidence further shows that practical application of evaluation tends to focus on effects where measurement is easy and techniques have been tested over decades. As also established by Newman-Askins et al. (2003, p.3), effects relevant for ITS projects in contrast to conventional roadway construction are:

- travel time reliability improvements
- improved control over travel choices
- environmental benefits due to smoother traffic flow (less stops)
- privacy compromise due to data/surveillance nature of some ITS applications
- higher risk of implementation due to high technological content and hence higher uncertainty attached to impact predictions.

However the items appearing in this listing are mainly found to be less frequently considered criteria in ITS project evaluations, (see Table 5). Reasons for this may be a lack of experience in how to measure or predict and valuate these impacts. Also, the difficulty of measuring or predicting the described effects may lead to the indication of infrequent incorporation.

Table 4: Key Measures of ITS Effects

Area	*Key measures of effectiveness*
Safety	Reduction in the overall rate of crashes Reduction in the rate of crashes resulting in fatalities Reduction in the rate of crashes resulting in injuries
Mobility	Reduction in travel time delay Reduction in travel time variability
Capacity/Throughput	Increase in throughput Increase in effective capacity
Customer[a] satisfaction	Difference between users' expectations and experience[b]
Productivity	Cost savings
Energy and environment	Reduction in emissions Reduction in fuel consumption

[a] Customers here roughly equal what is defined as users in 2.2.1.

[b] Various techniques and steps necessary depending on project and user group.

Source: RITA n.d., webpage: "ITS Evaluation Guidelines – ITS Evaluation Resource Guide"

Table 5: Effects of ITS Measures Considered in Evaluations

Frequently considered effects	*Infrequently considered effects*
Safety impacts (accidents)	Travel time reliability
Journey time	Driver distraction
Delay time	Network effects
Vehicle operating costs	Route diversion
Technical risk	Personal and community security
Emissions and noise	Modal impacts
	Liability and privacy issues
	Reliability and possible obsolescence of technology
	Interoperability and relationships between different applications of ITS

Source: Newman-Askins et al. 2003, p.11 - table compiled by the author

3 Methods of Project Evaluation

3.1 Objectives of project evaluation

3.1.1 Foundations of project evaluation and the role in decision making

The theory and practice of decision-making does not lie within the scope of this thesis. However, as there is a significant relationship between decision-making and project evaluation, the first lines of this chapter shall be dedicated towards this complicated issue. Decisions are important steps that in some way occur in every project planning, implementation and operation process. How the decisions are made, and which parameters influence them varies greatly. A prototypical concept of decision making is the rational approach which follows a sequence of steps to reach an informed decision. The process illustrated in Figure 7 is based on this concept. Evaluation, as it is understood here, is especially rooted in rational decision making as it provides the necessary information for qualified decisions and since it is also part of the structured process. Practitioners view this strict order as unrealistic and describe that decision-making often follows very different principles[35]. These practical variations of decision-making have led to intense academic debate, whereupon a variety of explanatory concepts were proposed. An overview related to transportation planning is provided, for example, in Meyer & Miller (2001, pp.57-68). Cascetta (2009, p.21) also observes the difficulties related to the rational approach but emphasized the value of the concept as a paradigm. This view is adopted here as the text concentrates on theory and methodology. Well recognized guidelines such as the UK's New Approach to Appraisal or the Finnish ITS evaluation methodology are consistently based on the rational-analytic approach (Macharis et al. 2004, p.445). For practical applications the critique of the rational approach to decision-making shall be kept in mind.

With his first words Saaty (1980, p.xi, preface) captures the essence of when evaluations are applied: *"The decision-maker, be he motivated by the need to predict or to control […]"*. Evaluation of a project is, generally employed in two cases: In the phase of planning a project it is a basis for decision making, then referred to as ex-ante analysis. Once a project has been established, an ex-post evaluation may be used to determine the success. Additionally, if there has been an ex-ante evaluation, ex-post evaluation provides insights on discrepancies between the predicted and actual effects. Prediction and valuation models may consequently be calibrated based on the results.

Project analyses generate structured information on the effects and their magnitudes, the goal of which is to provide clarity to decision makers and their constituents. In a consequent step, the effects can be valuated and aggregated. There are various methods providing a broad variety of options on how to achieve this. The results of such structured analysis and valuation processes

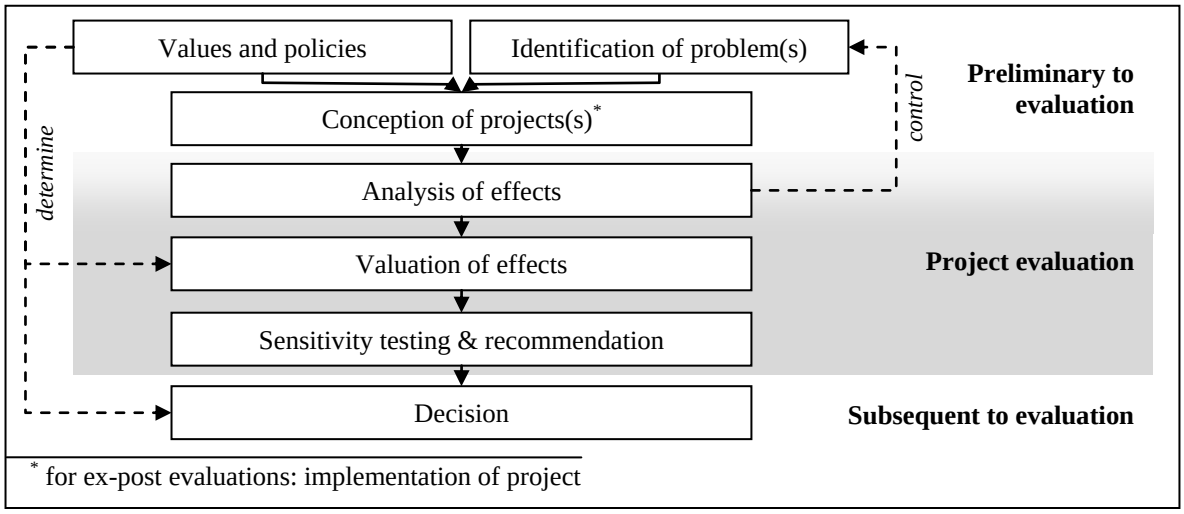
[35] Allegedly, decisions in both the public, but especially the private context, follow principles of personal preferences of decision-makers. Interpersonal relations play a major role in that respect. Evaluations in this opinion are established following the actual decision. A positive interpretation understands this as a posterior confirmation, or legitimization of the decision; critical minds believe that the evaluation is constructed to provide a justification of the decision.

provide information regarding the feasibility of the project and give answers to the question whether it is, or respectively was, advantageous to implement it.

Depending on the method, project evaluations may additionally serve the following goals of project planning: An evaluation might turn up deficiencies in the way a project was conceived or realized. Based on this information, adapting some aspects might make the project a lot more successful. Closely associated with this, Schott (2004, p.23) further points out that, within the evaluation, external factors impeding or promoting success may be identified, which is a central aspect of work done in the US. Participation of stakeholders can increase acceptance or in a preliminary manner identify sensitivities that may be decisive for the successful implementation of the project.

Some methods are reasonably applicable to a single project. Others however are only useful in ranking a given set of at least two projects. Given that the interest exceeds the collection of data on a given project, all methods include a comparison of at least one project alternative against a reference case. The reference case is usually a do nothing scenario. Analysts must pay attention to correctly execute the comparisons. The cases may only be compared within the same time period. If more than one project alternative is to be analyzed, evaluations usually aim to establish a ranking of the alternatives. If possible, this shall be complete and transitive. Depending on the method, some rankings are established based on internal comparisons. As they are of a relative nature only, they become obsolete if the set of projects is changed.

Figure 7: Evaluation in the process of project development



Source: Author

It is worth repeating at this point, although it was already stated in the introduction under 1.1, that the outcome of a project evaluation is not the decision for or against its implementation. An evaluation neither explains the process of decision making nor project development as such.[36] Instead, results contribute to the decision making process as described above. Decision-making is external to project evaluation. Sometimes evaluation results will simply be disregarded.

[36] In social sciences, the term program evaluation is also known which again differentiates between needs, process and outcome evaluation. Project evaluation here is understood as at the evaluation of outcome effects of technical projects.

Common steps of project development, following the rational decision making approach, are illustrated in Figure 7. The emphasis here is set on the evaluation. Naturally also the other steps could be broken down into more details. Steps necessarily preceding a project evaluation are the establishment of values and policies, the setting of goals and the definition of a project or a set of projects as well as the reference case.

3.1.2 Determination of evaluation objectives based on the interests of decision-makers

To identify an appropriate evaluation method, it is important whether the project is of a private or a public nature. Associated with this issue, it has to be determined whose interest in the project shall be satisfied. This is best displayed in a matrix, as presented in Table 6. The interests that are identified here influence the scope of the evaluation, the way effects are treated and thus, to a certain extent, they predetermine the method. The basic assumptions for Table 6 are that private decision makers will only pay attention to internal effects. Public decision-makers, on the other hand, are involved in decisions on public projects, and to some extent also in private projects; e.g. in the context of authorizations or subsidies that have to be granted. Due to their responsibility towards their constituents (generally various parties other than the project developer), effects that are external to the developer's calculation are also taken into account.

Table 6: Evaluation interest of decision-makers in public and private projects

		Project type	
		Private	*Public*
Decision-makers	*Private*	(1) feasibility, profits/return on investment, risk of project	(2) - *
	Public	(3) coherence with regulation, social effects fiscal impact	(4) social desirability justification before constituents, fiscal impact/cost coverage

* It is assumed that private agents do not have authority to decide on public projects. Thus, as they are not decision-makers on public projects, they do not have an interest as a decision-maker but solely as constituents. It is further assumed that the interest of the constituents is limited to the justification of a project, which is provided by the public decision-maker.

Source: Author

Potentially, further differentiation of the interested parties is possible. Undoubtedly, interest and lobbying groups should not be neglected and also the custodians of the funds financing the project have an interest in evaluation. In practice however, the main players in commissioning evaluations are the ones responsible for the measures; at least those regarding a large range of public policy programs (Widmer & Leeuw 2009, p.67). Possible conclusions are that other stakeholders do not possess the necessary resources to commission project evaluations. It may also be the case that they see projects sufficiently evaluated by their delegates or simply lack interest.

After the primary distinction whether a project shall be analyzed from a private or social point of view, the effects on the social plane may be categorized in three groups. The interest in either one or the other type of effect requires a different methodology. Following the concept presented by Schönbäck & Bröthaler (2002, p.598, Abb. 1), evaluation methods may address:

- functional aspects (based on which private profitability and social desirability may be calculated),
- the project's effects on the economic performance of a defined region and
- fiscal impacts on a public agent's budgets.

Functional aspects may include technical, political, social, ecologic, etc. effects evaluated in the light of special utility or damage categories or alternatively their impact on social welfare. The second item refers to project induced (marginal) changes the utilization of economic capacity in a region leading to value added. (Schönbäck & Bröthaler 2002, pp.598, 600)

3.1.3 Legal basis and regulatory requirements of project evaluation

The initial question to be answered in this subsection is whether there is a legal basis to project evaluation, such as a law determining what has to be evaluated by whom, when and how. In the EU this is the case with EIA, as is detailed in the respective subsection 3.2.7. Other methods are not prescribed as strictly although evaluation is required in various cases.

Regulatory requirement of evaluation is generally associated with activities of public agencies. Private project developers are not legally required to conduct the project evaluations listed under 3.1.4. Two exceptions may be mentioned, the first being EIA. Second, private projects receiving public support, e.g. subsidies, may require evaluation. (Bristow et al. 1997, p.52)

Article 170 of the Swiss Federal Constitution assigns the Federal Assembly the task of controlling the effectiveness of federal measures (Widmer & Leeuw 2009, p.65). Of course, further instructions are not included in the constitution but instead provided in hierarchically lower regulation.

In contrast, the Austrian Federal Constitutional Law[37] defines only the economic principles for public activities. Only the Federal Budget Act[38] demands that federal agencies evaluate the impacts of certain activities.

For regulatory measures, the primary objective is to assess the impact on the federal budget. Aside from the cost and revenue calculation, the benefits shall also be demonstrated. (Pichler 2009, p.41) Equally, in the US, the Presidential Executive Order 12291 first required an evaluation process for regulatory action of government agencies. It is very precise on the subject; even the decision criterion is defined. (Executive Order 12291 1981, sec.2 (b))

[37] B-VG Art. 51a Sec. 1
[38] BHG § 14 Sec. 1

In addition to the analysis of regulatory action, the Austrian Federal Budget Act recognizes isolated projects. Pichler (2009, p.41) interprets these as measures including financial incentives. However, the actual text describes isolated projects as undertakings which can also include the acquisition or production of goods or the provision of services. (BHG, §23, Sec. 1 and 2) Thus there is no indication that technical projects such as the establishment of ITS by federal agencies are excluded[39]. The §47 of the Federal Budget Act further details that isolated projects or programs comprising interrelated projects as described in §23, have to be subjected to an assessment whether the success of the program and the necessary measures are in concordance with the principles of economic conduct – thriftiness, cost-effectiveness and fitness for purpose. The assessment has to be provided by the federal agency directing the project.

An area where evaluation requirements are often included is sectoral regulations. First requirements and standards for analysis pointing at CBA were included in the US Flood Control Act and the Navigation Act in the 1930s. In Austria, one area of federal regulation with direct consequences for ITS is the Federal Immission Protection Act – Air (IG-L). Measures that are suggested for achieving the goal of maintaining airborne pollution below the limits set include dynamic traffic management. (IG-L §14 Sec. 6a ff.) In IG-L §9a Sec. 7 it is specified that programs directed at assuring compliance with immission limits have to be evaluated regularly. The main focus of this evaluation shall be the effectiveness of the program and the contained measures in terms of their contribution towards the objectives set forth in the IG-L. Further evaluation objectives or a method for the process are not specified.

Similar vagueness of evaluation requirements and guidelines in other Austrian sectoral regulations is asserted by Pichler (2009, p.43)

As for the choice of methods, regulations rarely include specific requirements. Gamper & Turcanu (2007, p.299) identify some rare legal requirements of MOA in Italian and US legislation. In the Austrian case delineated above, only the purpose of the assessment is stated. Upon this, it is possible to conclude which methods will have to be applied. The explicit requirements are limited to analysis of fiscal impacts or effectiveness measures regarding the objectives.

3.1.4 Overview of selected evaluation methods

Choice of an evaluation method will follow the purpose of the analysis. These purposes may be derived from the project's characteristics. The effects to be evaluated and especially the focus of decision maker interests play a dominant role in this context. A list of evaluation purposes derived from 3.1.2 is displayed in the left column of Table 7.

Accordingly a set of evaluation methods that generate results allowing insights regarding the listed purposes is compiled in the right column of Table 7. Many of the most commonly applied methods are listed. The practical infinity of evaluation methods and variations cannot be reflected. The methods distinguished here will be described in section 3.2.

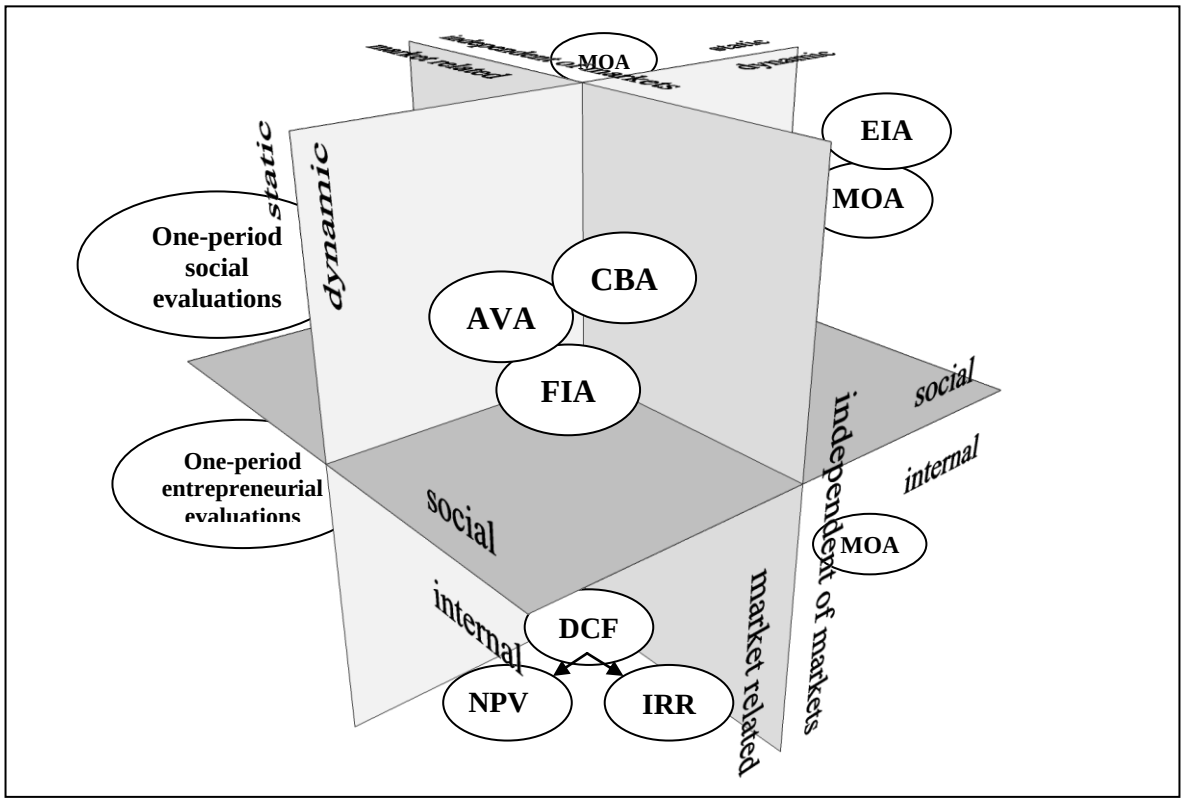
[39] This is a direct interpretation of the wording of the law and not a legal expertise.

Table 7: Selected methods for identified evaluation purposes

Purpose of evaluation (Asses the projects effects regarding its -)	*Proposed method*
- internal profitability, - cost coverage	Discounted cash flow analysis (DCF)
-contribution to social welfare	Cost-benefit analysis (CBA)
- value added to a regional or national economy, - employment effects	Analysis of value added (AVA)
- impact on public budget	Fiscal impact analysis (FIA)
- satisfaction of objective(s) compared to costs	Cost-effectiveness analysis (CEA)
- contribution to various objectives	Multi-objective analysis (MOA)
- satisfaction of formal legal standards regarding environmental stress	Environmental impact assessment (EIA)

Source: Author

Figure 8: Location of selected evaluation methods in a spatial diagram regarding the three basic differentiations



Source: Author

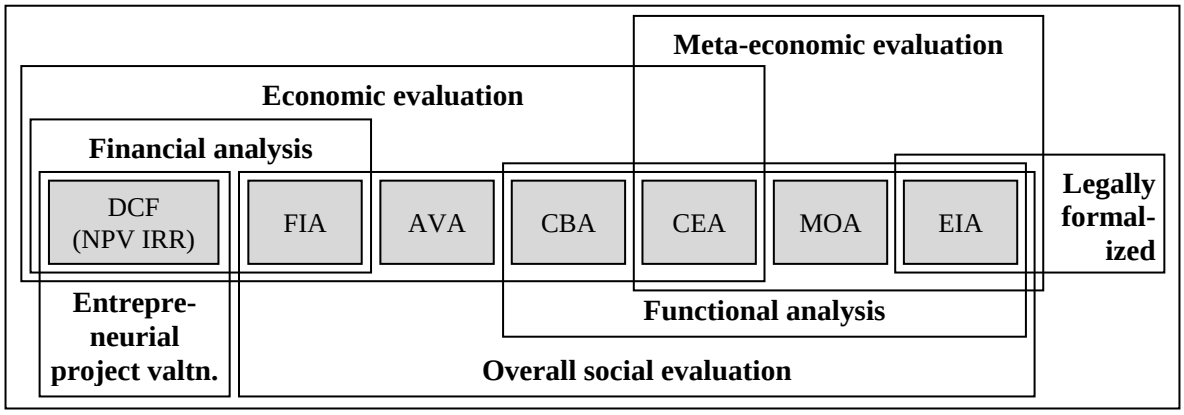
This overview shall also provide orientation regarding a set of important characteristics by which evaluation methods may be differentiated. The first characteristic describes whether an evaluation method is static or dynamic regarding the integration of varying magnitudes of effects in different periods. Second, it has to be differentiated whether the method focuses on internal effects only or takes a broader scope of effects into account. Social, in this context, refers to incorporating both internal and external effects. Third, it may be determined whether the evaluation method is more or less closely associated with market transactions. This should not be interpreted as an exact differentiation regarding the use of market-based and non-market-based valuation techniques. If

these three dimensions are used to construct a cube, the selected evaluation methods can be located in the certain quadrants based on their characteristics. Figure 8 visualizes this concept.

Some sectors of the cube are not visible (e.g. static, internal, independent of markets). Here, analyses of technical or legal feasibility are situated. In other sectors no methods are attributed (e.g. static, social, market related). In this case, naturally the evaluations which allow incorporation of dynamic effects can also be executed as static evaluations. Mostly however, evaluations including social effects are conducted at a high level of complexity and seek to account for variations of effects in future time periods. Evaluation methods related to the measurement of effectiveness to a certain extent allow the integration of initially qualitatively described effects. As will be shown in in such cases the transformations to quantitative scores are often debatable. Assumptions on the variation over time periods are even more difficult to predict. Due to these uncertainties some elements of the evaluation may remain static. Further, measures of effectiveness can also be limited to internal effects. These issues are addressed by the repetitive location of the “MOA” method in various sectors.

As some evaluation methods share certain characteristics, they can be combined to groups. Figure 9 unites the methods according to their limitation on economic or accounting effects. To emphasize the importance of this differentiation, the distinctiveness of internal and social evaluations are included as characteristics here.

Figure 9: Classification of Selected Evaluation Methods



Source: Author

A detailed comparison of the methods analyzed is provided in Table 8 in subsection 3.2.8.

3.1.5 Common situations of evaluators and analysts

It is a rare case that decision-makers possess the expertise to conduct evaluations. Even if they do, it is doubtable that they are able to dedicate enough time to establish a comprehensive project appraisal. It may be assumed that decision-makers principally outsource this step in preparing decisions. Stockmann (2007, p.27) even views the fact that evaluations are conducted by especially qualified persons (experts) as an intrinsic quality of evaluations. These experts (in the relevant literature the terms analysts and less frequently evaluators are coined) may be part of the organization which aims to develop or which operates a project. However it is also a possibility that the evaluations are conducted by external analysts. Internal and external evaluations may be

associated with advantages and disadvantages. In general, internal evaluations can more easily draw on inside information; external evaluations are often associated with a higher level of independence (Brandt 2007, pp.169-171). In case of external evaluations, it is further important to distinguish between those studies commissioned by the organization developing/operating the project or whether the evaluation interest is external. In practice, the independence of the evaluation may be influenced by this factor.

Organizations and individuals assuming the role of an analyst may originate from different backgrounds. As explained, any project developing/operating organization may also conduct their evaluations. External organizations offering evaluations as a service are mostly academic institutions, technically specialized (independent) institutions and also consulting enterprises.

Centralized public evaluation agencies do not exist in European states such as Germany, the Netherlands, Austria and Switzerland (Widmer & Leeuw 2009, p.66). Public controlling agencies, due to their tasks, often become evaluators, but then this is rather associated with ex-post evaluations. Regarding ITS, the Austrian Federal Court of Audit analyzed the freeway telematics program of the ASFINAG in a 2009 report. In that specific case, it revised, retraced and criticized a project evaluation that had been previously established by an academic institution (Rechnungshof 2009, see also the first example of an ITS evaluation presented as part of this thesis under 4.1). However, it is also possible that controlling agencies themselves conduct evaluations.

A significant share of evaluations of measures in a specific field is commissioned by the responsible public agencies. Whether they will be conducted internally or contracted externally depends largely on the national evaluation culture. (Widmer & Leeuw 2009, p.67f.) The current tendency appears to favor outsourcing of the task. Even in countries with a traditionally well equipped bureaucracy this appears to be the situation, as is described for the case of Austria by Pichler (2009, p.50). Benefactors of this development are external analysts; mainly universities, private research institutes and, in some cases, consulting firms.

3.2 Description and comparison of selected methods

From the variety of interests, addressees, and project aspects that have an influence on evaluation, it is understandable that many methods have been developed. This subsection provides an overview. Because of the large number of methods available and the fact that, in many cases, variations and derivates exist, it is not possible to list all exhaustively. Instead a selection of methods is presented which are commonly used or which are especially relevant.

3.2.1 Entrepreneurial evaluation methods

In a first step, an approach to the evaluation of projects from an entrepreneurial point of view shall be presented. Textbooks in business economics and business administration often refer to the issue as project valuation. The purpose of the associated methods is to provide insight on the profitability of a given project. This interest is mainly associated with the private sector (see Table 6). However, this is not exclusive. Entrepreneurial project valuation may be employed by any agent performing economic activities. This includes public agencies as well. The process of entrepreneurial project

valuation is especially relevant for agencies providing goods or services. As a current trend in public administration is to incorporated public agencies as bodies under private law, the importance of the internal evaluations may further increase. Especially for the public sector, the potential of the entrepreneurial project valuation to estimate or identify the actual amount of public funding necessary may be of interest as sensitivity towards the scarcity of resources increases.

Basic to any private entrepreneurial activity is economic survival. Depending on the situation of the enterprise, various factors contribute to survival such as customer satisfaction, growth, leadership in markets, etc. The key however is the profits resulting from success in business which lead to growth of the enterprise, or in other words, added value. Cash inflows that exceed cash outflows are the basis of profits. Therefore every project will have to be analyzed towards its performance in that respect. Only monetary effects are taken into account and market prices are used for the calculation. Inflows normally result from sales of goods or services but can also result from transfers following different motives. Outflows are composed of the necessary investments (initial investments, replacement investments), expenses during operation and imputed interest charges.

The simplest way to analyze a project is to compile the above mentioned cash flows and compare them for a single period of operation. In many cases this will be one year, or an accounting year. Significant onetime cash flows, such as initial investments, are taken into account through the annual depreciation. The period for which the project is analyzed should be representative for the operation of the project. Wöhe (2000, pp.628-634) lists three static project valuation methods which are applied for a single period:

- Cost comparison method,
- Profit comparison method,
- Return on investment (ROI)

Gathering the necessary input data for the cost comparison method is likely to be the most uncomplicated step in the evaluation process. At the same time, the result of the cost comparison is very important as it emphasizes the resource input necessary. Some project alternatives may already be discarded since the costs exceed the available budget[40]. A correct comparison of project alternatives is only possible if the revenues of all project alternatives are equal. If this is not the case, the profit comparison method should be applied. In case the magnitude of the possible revenues is unknown, it is risky to rely on the cost information only as it is not determined that the revenues can cover the costs (ibid., p.630).

The profit comparison method calculates the profits of a project by deducting the aggregated costs in a representative period from the aggregated revenues in the same period. While the concept is very simple, the actual determination of revenues may be rather complicated. Especially when similar experiences are unavailable, assumptions are employed. This of course involves a risk of its own and may significantly influence the result. Interpreting the result of the profit comparison

[40] In some cases the budget constraint may be neglected if the project's size is marginal compared to the availability of funds on the capital market. In this case, the cost of the imputed interest charges as part of the project costs must not be overlooked.

method again is as uncomplicated as the concept: if a single project is analyzed it shall be adopted in case it produces profits; facing several alternatives, the most profitable shall be chosen.

While the profit comparison method already is a good indicator, it does not take the amount of the tied capital into account. However, examining the possible profits in the context of the necessary investment is a primary concern of investors. Therefore the ROIs of project alternatives shall be compared. For the ROI, various calculation methods are proposed depending on the specific situation of the analysis. Wöhe (2000, p.631) proposes the following formula:

$$ROI = \frac{profits + imputed\ interest\ charges}{average\ tied\ capital} \cdot 100$$

The ROI may be viewed as a first approximation to the internal rate of return (IRR) (Loderer et al. 2010, p.38). Investors may use the ROI to compare their gains from a project with, for example, the current interest rates. It is therefore especially important for investments in the private sector.

By extending the evaluation of a project from a single period to multiple periods, another set of questions can be answered: what is the overall internal benefit of a project during its lifetime, or how long it takes to redeem initial investments. In general, the methods to gauge these issues are based on the cash flows of a project, meaning the actual incoming and outgoing payments. If the necessary information is available, the development of these cash flows over time can be integrated in the analysis. Hence the calculation becomes dynamic.

The simpler approach is the calculation of the payback period, also referred to as the pay-off method. The principal interest is to find out when the sum of excess operational cash inflows over cash outflows is at level with the initial (capital) cost. A time frame is arbitrarily set by the decision-maker wherein the cumulated net cash flows must be positive. For the operational in and outflows, often a representative period of operation is assumed and carried forward. If the dynamic cash flows are known, they may also be used instead of the standardized cash flows. In general, investors are interested in a short payback period. As an alternative to determining the length of the payback period, it is common practice to arbitrarily set a payback period and analyze whether or not the project is able to meet the exigency. The advantage of the pay-off method is that it usually analyzes only few operational periods. Hence, the time frame of the analysis is short compared to the full lifetime of a project. As cash flows in the far future are ignored, it is not necessary to dedicate significant resources to predict them. Also, for the short time frame of a payback period it is usually not necessary to discount the cash flows in future periods. Thus uncertainties in long term predictions are avoided and, the complicated search for the adequate discount rate is avoided as well. Obviously in this case, comprehensiveness of the analysis is traded for convenience and low cost of the method.

The most professional method of entrepreneurial project valuation is the discounted cash flow analysis (DCF). This method calculates the net result of the project for each period of the project's life. Naturally, it is necessary that the future cash flows are known or at least predictable. If this is the case, the DCF's potential in contrast to the previously described methods is obviously the increased level of detail. A more precise evaluation becomes possible. Dynamically developing

regular cash flows may be taken into account as well as non-recurring investments in periods other than the initial one and revenues from the liquidation of investments at the end of the project's life span. Hence investors may compare projects regarding the moment in time when investments are necessary or profits occur.

The concept integrates the assumption that presently available funds are valued higher than those only available in future time periods. Additionally, cash flows to be effected in near time periods are more important than those occurring in the far future. Therefore cash flows in future periods are discounted. The choice of an adequate discount rate is critical and at the same time difficult. The effect the discount rate has on the result of the analysis is especially significant if project alternatives are compared which produce major cash flows in different time periods. Establishing a proper discount rate for a project or a set of projects will mostly be based on the expected interest rates on capital markets. Adjustments are made according to the risk of the project. The discount rate must also be set in accordance with the treatment of inflation in the future cash flows. In essence, the discount rate reflects the investor's desired minimum rate of return (Wöhe 2000, p.636). Identification of an adequate discount rate is a complex procedure which cannot be treated in detail here.[41]

To facilitate the interpretation of the DCF, the result is usually aggregated. All cash flows during the project's lifespan, represented in their present worth, may be summed up and. This criterion is called the net present value (NPV). The NPV reflects the internal gain or loss of wealth for the investor at the initiation of the project. A positive NPV in general suggests that the project should be implemented. A negative internal NPV indicates that a project will not be advanced by private investors unless it is subsidized at least in the amount of the NPV (ibid., p.639).

Calculation of the NPV follows the formula presented below:

$$NPV = \sum_{t=0}^{T} \frac{(CF_{in} - CF_{out})_t}{(1+i)^t}$$

NPV	*Net present value*
CF	*Cash flow*
T	*Number of operational periods*
t	*Period*
i	*Discount rate*

As an alternative to calculating the NPV, the cash flows established in the DCF may be used to calculate the IRR. As indicated above, the IRR is an indicator of profitability for the investor. To calculate this criterion, the NPV formula may be used. The NPV is set to zero and *i* is replaced by the variable *r*. The equation is iteratively solved for *r*. Investors may use the IRR to compare it with the prevalent market interest rates, or the IRR of other project alternatives. The rule here is: the higher the IRR, the better the investment. From a private investor's perspective it should at least be

[41] Guidance on the process of establishing the discount rate for private project valuation and its discussion can be found in the according specialist literature, an example of which is represented by the comprehensive publication of Loderer et al. (2010).

one unit higher than the market interest rate. While the IRR allows a larger variety of comparisons, it is also associated with notable problems, a series of which are described by Loderer et al. (2010, pp.181-193). Amongst these are cases where no IRR may be calculated and others where more than one IRR prevents the effective use of this criterion in the decision making process. Especially when the net future cash flows of projects often change between positive and negative values, the IRR becomes increasingly difficult to calculate. Also, when comparing projects with very different cash flow structures, the IRR favors projects with higher cash flows in the near future even stronger than the NPV. In case the IRRs result is inconclusive, the NPV still generates a reliable result. In general, it is advisable to take both results into account when deciding upon a project.

In practice, managers of private enterprises prefer simple methods. The Institute of Financial Management at the University of Bern conducted a survey of the investment criteria chosen by the most important Swiss companies. The largest share, over 70% of the respondents, used the payback method whereas 36% applied the NPV and only about 30% rely on the IRR[42]. This is due to uncertainties regarding the prediction of net cash flows and setting the appropriate discount rate. A different criterion is preferred by managers in many cases. For large projects, or when evaluating the introduction of new products and services compared to maintenance and renewal, the NPV becomes more attractive compared to the payback method.

For private decision makers, the result of the entrepreneurial project valuation may have a very direct consequence: If the NPV or IRR results are unsatisfactory, or other criteria such as the payback period are not met, the project will most likely not be adopted in the given form.

Regarding the social desirability of a project, the entrepreneurial project valuation methods cannot provide an answer. Expressed in economic terms, the basic rule of the entrepreneurial valuation is the optimization of the producer surplus (Winkelbauer 1996, p.18). Both positive and negative external effects are neglected completely. This is the most important reason to continue project evaluation from a societal point of view.

Public decision-makers, who in principal should focus on the social project evaluation results, may also find the results of the use the entrepreneurial project valuation useful. Based on it, the necessity of public investment may be assessed. Internally profitable projects do not require public funding. As these projects are developed by private agents, public funds are free and may be dedicated to tasks which are socially desirable but not internally profitable. Once public involvement is decided, the result of the entrepreneurial valuation is not necessarily the most relevant decision criterion. Public or political interests will most likely weigh more and thus may lead to adoption of the project in spite of a negative internal result. The information provided by the entrepreneurial project valuation however remains important, for example, to plan transfer payments within the hierarchy of public agencies or to determine when and to which extent the incursion of debt becomes necessary. Liquidity and the ability to meet financial obligations are also issues public agencies cannot neglect. However, the entrepreneurial project valuation is only a first approximation since the factors influencing public budgets are to a large extent determined by tax revenues. This issue is further treated in subsection 3.2.4.

[42] Apparently multiple choices were allowed.

3.2.2 Cost-benefit analysis (CBA)

It is understood that CBA is the oldest established evaluation method, its principles defined by Jules Dupuit in 1844. Already at this time, it was linked to transportation planning, more precisely construction of roads and bridges. As the method was further developed, it became applicable for a large variety of project and program evaluations. Many authors have published on both the theoretical and practical aspects of CBA. One of the most renowned publications was authored by E.J. Mishan, now in its 5th edition (Mishan & Quah 2007).

Within the present thesis, the term CBA is associated exclusively with the evaluation method focusing on the appraisal of a project based on its monetary or monetized total[43] effects. This is coherent with the understanding in the relevant literature (Boardman et al. 2006, p.2; Schönbäck et al. 1997, p.3; Gramlich 1990, p.41). Within this framework there is room for the application of various techniques and there is no strict rule on how exactly a CBA must be performed. However, the basic principles and elements do not change (Winkelbauer 1996, p.65).

In the practice of planning and policy making, the term CBA is highly regarded and in the public discourse it is often associated with objectivity. Consequently, the term is often chosen to describe any more or less structured approach to compare more or less clearly defined or measured project effects. As the term is not an intellectual property of any kind, its alienation is not prohibited. Hence it is necessary to examine analyses denominated CBA more closely before it can be ascertained that a CBA sensu stricto is at hand.

CBA analyzes a project based on its contribution to social welfare. The underlying objective is to choose those projects providing the maximum welfare in the light of scarce resources (Schönbäck et al. 1997, pp.3-4). While welfare economics assume that private decisions on efficient markets automatically lead to this result, this is not the case for public decisions. Therefore, CBA is often applied to public projects or initiated by public interest. Conducting a CBA may be very complicated depending on the type of effects relevant and the ease of access to information on effects. Thus, it is often employed for large projects only where the cost of the evaluation is marginal against the cost of the project.

Methodologically, the CBA draws on two disciplines. Measurement and weighting of effects are based on economic principles, as are the decision rules. The paradigm of welfare economics and the theory of public goods are the main foundations in this respect (ibid.). In coherence with the Kaldor-Hicks criterion[44], CBA assumes that a project is desirable if its benefits outweigh its costs and the winners would be able to compensate losers. The accounting framework to structure and aggregate the data follows the same concept as the DCF as explained in subsection 3.2.1. Hence, discounting and the choice of an appropriate discount rate is also a relevant issue in CBA methodology. Further details are discussed in the “Excursus on the choice of a discount rate”.

To facilitate aggregation, all items are counted in monetary terms. In some cases, this is referred to as standardization through monetization (FSV 2010, p.20). This constitutes probably the most

[43] Alternatively the term social is used.
[44] Established in the fundamental publications by Kaldor (1939) and Hicks (1939; 1940)

discussed issue within the CBA methodology. This discussion is twofold and may be differentiated into (1) the debate of the implied advantages and problems and (2) the development of techniques to adequately use monetary values. As follows, the relevant arguments of the former issue are treated. The subject of monetization techniques is dealt with in the "Excursus on the incorporation of monetary effects and monetization" at the end of this subsection.

The obvious advantage of the CBA's focus on monetarily valuated effects is that a result presented in a monetary dimension is easily understood by many people. Additionally, by using the (objective) value of prices to weigh effects, the performance of a project becomes widely comparable. This is a significant advantage compared to other methods that evaluate functional aspects of a project (such as MOA or CEA, (see Figure 9) and use a set of values internal to the respective evaluation process. Finally, Schönbäck et al. (1997, pp.3-4) register that CBA allows to make implicit values stakeholders have for certain goods visible. While this is a gain of knowledge in itself, in CBA these detected valuations are incorporated in an overall analysis.

However, the use of monetary values is prone to criticism. Arguments often refer to ethical concerns of placing a monetary value on certain goods. The most frequently cited example in this context is the value of a human life. Further, the use of market prices or deriving values from willingness to pay, implies that these values reflect human preferences only. By some, this is refuted as anthropocentrism (ibid.).

An argument following up on this issue is the result of the technical inability to monetize all project related effects. This may lead to an overrepresentation of effects occurring in a naturally monetary dimension or which are easily monetizable (Litman 2006, p.5). Even if the greatest care is taken in the selection of effects and the establishment of the associated monetary values, certain effects are not monetizable. Schönbäck et al. (1997, p.3) accept this fact as an inherent part of the CBA method and emphasize that any other effects have to be taken into account at a meta-economic evaluation level and finally, in political decision making. Often, this is addressed by including a description of non-monetizable effects with the CBA. A more long term solution lies in the constant advancement of monetization techniques. G. Weisbrod et al. (2009, p.333) observe this solution to the problem of exclusion of effects in CBA. In case a present evaluation finds the most significant benefits of a project to be of a non-monetizable nature, the practical solution is to simply choose an evaluation method other than CBA.

To achieve the comparison of social effects versus opportunity costs, the CBA begins by assessing the internal effects occurring to the agent developing or operating the project. In that, it is equal to an entrepreneurial project valuation. Additionally, external effects of a both positive and negative nature are taken into account. At this point, it is important to note that a CBA focuses on real effects only and neglects pecuniary effects, as defined under 2.3.2.

The result of a CBA may be expressed in various criteria, which in some cases prooduce different rankings if a set of projects is compared. Similar to the dynamic entrepreneurial evaluations the (in this case social) NPV and the social rate of return (SRR) may be used. The benefit-cost ratio

(BCR)[45] is also common. Other decision criteria such as the cut-off period, social pay-off period or average rate of return are listed by Mishan & Quah (2007, pp.125-127) but appear less frequently in the theoretic literature.

Several authors favor the presentation of a CBA's result as the (social) NPV – and consequently the decision rule of favoring the project with the maximum net benefit (Boardman et al. 2006, p.33). Even radical approaches such as *"Do not even get tempted to show benefit-cost ratios […]"* (Gramlich 1990, p.230) are found. In other cases, analysts chose other criteria. The CBA conducted as part of the German FTIP 2003 evaluation framework exclusively uses the BCR for the ranking of alternative projects (Birn et al. 2005b, p.30). On the subject of whether to prefer the NPV, BCR or SRR Mishan & Quah (2007, pp.141-142) find that there is no final argument in favor of or against one of the criteria. The SRR for example is preferred if a given capital budget shall be allocated to a set of projects. The NPV criterion undoubtedly gives the best answer to which single project contributes the most to social welfare, neglecting possible budgetary constraints. The BCR will prefer highly profitable projects unimpressed by the absolute amount of net benefits generated.

A possible critique of the BCR is that its result may be influenced by the determination whether negative effects are costs or (negative) benefits and hence take effect in the numerator or the denominator respectively. However, this is only valid if the definition of benefits and costs remains unclear. As there is no exclusive rule in CBA, this may be the case. However the general suggestion is to determine all inputs to the project as costs and all outputs (even though potentially negative) as benefits.

The most evident resolution to the debate on how to formulate a CBA's result is demonstrated by Schönbäck et al. (1997, pp.285-287) who list all of the criteria and appended information regarding the relevance.

Unsolvable problems with CBA are mainly linked to the claim of providing a social (total) evaluation of a project. As elaborated, some effects are simply not tangible within this method. Further, resulting from the foundation on Kaldor-Hicks efficiency, CBA is unable to indicate distributional effects or give an answer to the desirability of redistribution effects. Attempts to remedy this issue include the distributionally weighted CBA. Simplifying the concept, it means that effects occurring to poor stakeholders are weighted higher to reflect their higher appreciation of economic effects[46]. However, the CBA's indication on the economic efficiency of a project is lost if additional weights are introduced. Generally, it is suggested to refrain from distributional weights in CBA or at least provide both the unweighted and the modified results. If the CBA method is conceived as limited to revealing the allocative efficiency based on monetary and monetizable effects, and hence all other aspects are to be resolved through methods specialized on the respective issue, these problems are not severe.

[45] The BCR is defined as $Benefits/Cost$ and gives a ranking equal to the ratio of excess benefits to cost $(Benefits - Cost)/Cost$ (Mishan & Quah 2007, p.144).

[46] The assumption is rooted in the concept of the marginal utility theory. A person with a lot of money will appreciate an additional unit less than a person with less money.

Possible errors in CBA are associated with the above mentioned critical issues of correctly adjusting monetary values and discounting. If possible, variations should be incorporated in sensitivity analysis. In addition, the issue of double counting[47] is emphasized in relation to CBA. Although double counting should be avoided in all aggregations, its visibility (and hence the attention) in CBA is a result of the standardization of all effects in monetary values.

Since CBA is one of the most used methods of project evaluation, it has also been applied to ITS measures. Aside from the examples described in chapter 4, various other references to applications have been found during the research. A notable quantity of experiences is hence available.

Excursus on the incorporation of monetary effects and monetization

Advantages and disadvantages of the use of monetary units

The use of monetary values in evaluations has various advantages. If they are used consistently throughout the evaluation, the homogeneous dimension is most practical to aggregate results. Additionally, assigning a monetary value to an effect allows its weighting. In principle, prices are the basis of monetary values. In the case of market prices, these values are quite easily observable. A further quality of using prices as values is their objectivity compared to weights established, often subjectively by individuals or groups, solely for the evaluation. Following the basics of economic theory regarding the establishment of prices, it may be deduced that using prices as monetary values provides a dual function: Prices paid are able to reflect the (minimum) value an individual, a group or society as a whole places on a certain good. At the same time, in an ideal case, the price is determined by the necessary input factors to establish the good. Thus, in theory, an evaluation based on values that reflect efficient allocation, will also produce a result that proliferates developments under this objective.

A first critique of the use of monetary values based on prices may be that goals other than efficiency are not reflected. To respond to this issue, it is in some cases possible to adapt the methodology. Alternatively, other evaluation methods have to be employed, as discussed in subsection 3.2.6 for example. Problematic issues in the context of markets and prices are often associated with the deviations between theory and practice. First, markets may be distorted and, as a consequence, do not reflect the actual value of a good. Possible reasons for such distortions are, amongst others, incomplete information of market agents or external interventions. Second, prices of goods may have been set arbitrarily or following other rationales than that of perfectly competitive markets. Third, for several goods, markets and consequently prices, do not exist or transactions may be effected covertly. Hence, it is not possible to observe the monetary value attributed to the good in question. Finally, in some cases some people view the association of a price with specific goods as unethical. The best example for this case is the ongoing discussion of setting a monetary value for (human) life.

[47] Mackie & Preston (1998, p.5) provide the following example: *"[T]he primary impact of a transport scheme may be the reduction in travel times. The secondary impact is improved accessibility to work, schools, shops and leisure facilities. The tertiary impact is the increased economic activity that the transport scheme has promoted. Provided generated travel has been correctly forecast, all of the secondary impacts and most of the tertiary impacts are merely downstream manifestations of the primary impact."*

In spite of the difficulties associated with the use of monetary values in evaluation, the advantages of the methods relying on them apparently are considerable. To enhance the accuracy of these methods and the scope of effects that may be incorporated in the evaluation, techniques have been developed to properly adjust observed (market) prices and attribute monetary values to effects including goods that are not exchanged on markets.

The use of observed (market) prices as monetary values and adjustments to market prices

Evidently, the use of observed prices (if available) to determine the monetary values is the easiest approach. Consequently, a principal interest is directed at when observed prices may be used as values in evaluation processes without further adjustments.

Regarding the entrepreneurial project valuation, the issue is little complicated. As the interest in this case is focused on internal effects, only those factors actually felt by the developer/operator of the project are of concern. If monetary values are available, it can be assumed that just these prices will directly affect the situation of the relevant stakeholder, independently of how they were established. Adjustments to observed prices are consequently not necessary. If the project itself induces effects that have an impact on market prices[48], this should be taken into account in the evaluation.

For project evaluations conducted from a societal point of view (e.g. for projects where public agents are involved), the situation is more complicated. In this case, the actual value or cost of a good to society should be determined. If an observed price was established in an efficient market, it reflects the cost or benefit of the good to society. Following the basic rationale of welfare economics, in efficient markets, resources are allocated in a way that opportunity costs do not arise and are thus not reflected in the prices. At the same time, this price determines the value the society holds for the last marginal unit of the good. In all other cases, that is if markets are not efficient, it must be assumed that the price of a good does not reflect its true value; the value of the good may be either overstating or understating the social value or cost.

Adaptations of the market prices hence become necessary. Boardman et al. (2006, pp.76, 93) emphasize the distinction between project inputs and outputs which generally affect different markets. Values of project benefits (outputs) should accordingly be established based on the concept of willingness to pay[49]. For inputs used in the project, the actual cost to society must be determined. This includes the cost of the necessary factor inputs which includes the remuneration of dedicated capital. The resulting corrected price is generally referred to as shadow price. The observed price is corrected for externalities, monopolies or public market interventions. In both cases, the determination of the actual value or cost is dependent on many factors such as the character of the market distortion causing the need for correction and the detailed situation of the project (e.g. its impact on markets, elasticities on these markets or the source of financing for the project).

[48] An example is the consumption of large amounts of a resource while production of this resource cannot be expanded accordingly.

[49] The willingness to pay is understood to reflect the monetary value an individual attributes to a good.

Monetary valuation of effects without prices

For many of the most important effects induced by transportation projects and ITS, proper markets do not exist. Typical effects that have to be monetized are time savings, safety benefits or environmental impacts such as pollution or noise. In these and other cases, prices cannot be observed directly. The absence of markets may be associated with the characteristics of the good; for example its consumption may be nonrivalrous or its occurrence may not be controllable. In these cases, analysts often turn to associated goods that are traded on markets and attempt to derive the implicit price of the non-traded good. In some cases, the option value[50] or the existence value[51] of a good may also be of interest in an evaluation. These valuation concepts are often applied to certain ecological effects as for example indicated by Hauger (2003, p.187) in the light of environmental protection.

The variety of techniques to determine monetary values for non-monetary goods are categorized into two groups by G. Weisbrod et al. (2009, p.334):

- Techniques that express benefits in terms of avoiding losses
  - Damage costs
  - Control or Prevention Costs
- Techniques that express benefits in terms of improvement value
  - Revealed preferences: inferred willingness to pay
  - Stated preferences: contingent valuation
  - Economic modeling: projection of income growth

In principal, a rule which monetization technique shall be used to weigh a given effect cannot be established. It is not always the case that the analyst is able to choose, but often more than one method may lead to an acceptable result. As an apodosis to their listing of monetization techniques G. Weisbrod et al. (2009, p.334) state that each approach is associated with a systematic bias. An empirical confirmation of this statement is provided by Shires & de Jong (2009, p.321). In a comparison of studies to determine the value of travel time savings, it was found that the use of one or another method to determine the monetary value may have an impact on the level of the value. The analyzed case showed that lower values result from combined stated preference and revealed preference studies when compared to studies using observations only or calculating the value from cost savings. Winkelbauer (1996, pp.86-114) analyzes how some of the most important effects of transportation projects may be evaluated: Travel time, for example, is an especially complicated issue as different trip purposes require distinct valuation approaches. The value of business trips may be derived from average salaries as it is assumed that the salary reflects the marginal productivity of labor. In this case a market for time exists where a price for time is established.

[50] Option values occur ex-ante to a project if stakeholders are *"willing to pay something for the option to consume the commodity in the future"* (B. Weisbrod 1964, p.472) even though the exact future situation regarding prices, qualities and quantities of available goods, etc. may be unknown (Boardman et al. 2006, p.211).

[51] The existence value refers to an individual's willingness to pay for goods that he or she never actually uses and constitutes a proper benefit category (Boardman et al. 2006, p.222).

Eventually, corrections may have to be made. In contrast, there is no market for leisure time and hence the values must be established through revealed preference or stated preference techniques. Various studies determined that the value of leisure time equals 20 to 50 percent of working time (ibid., p.87). Here, econometrics provides an additional argument to incorporate detailed assumptions or measurements of trip purposes in evaluations. Further differentiation must be made regarding the appreciation of travel time reliability. This is practically a completely different effect and values will likely be associated with the aversion to risk of delay. An insight to the application of stated preference surveys to determine a set of values likely to be relevant for ITS projects is presented in Z. Li et al. (2010). There, the application of a stated preference technique for attaining a value for travel time reliability is described and the results of several studies compared.

Values proposed for the use in transportation project appraisal

As elaborated, establishing the monetary values for the use in evaluation is mostly a specialist's task. Often, extensive econometric surveys will be necessary. Usually it is not possible to perform such an undertaking as part of a project evaluation. Exceptions are more detailed studies to adequately adjust the monetary value(s) for the most important effect(s). More frequently, the analysts performing evaluations rely on pre-established figures, so called plug-in values.

Plug-in values are often published in line with standardized evaluation frameworks such as the New Approach to Appraisal in the UK or the FTIP in Germany. Further sources for plug in values are professional guidelines. In Austria, an accepted standard providing monetary values for effects that may occur in the context of transportation projects in general are the RVS guidelines.

In this latter case, an updated version of the guideline is to be released in a matter of months after this thesis is submitted. While the 2002 version dedicates one table to monetized values of project outputs, the issue is treated in significantly more detail in the revision. The revised RVS for Cost-Benefit-Trials in Traffic and Transport also proposes significantly higher monetary values in some cases. For example, a person hour spent on a business trip was formerly valued with 8,50€ on the basis of 2000 and will in the future receive a value of 30€ on the basis of 2009 (FSV 2002, p.10; FSV 2010, pp.25-31). Even accounting for necessary adjustments due to inflation, the new value is three times as high as the one proposed in 2002. Comparing this specific set of values with the ones used in the German FTIP (19,94 €/person hour on the basis of 1998, see Birn et al. 2005b, p.133) the Austrian values were previously significantly much lower and are now notably higher.

Excursus on the choice of a discount rate

The discounting of effects occurring in future time periods is an element mainly used in evaluation methods focusing on monetary or monetizable effects. In literature, it appears mainly in the context of the DCF and the CBA. Discounting is thus not limited to either entrepreneurial or social evaluation methods. As the choice of the discount rate may strongly influence the result of an evaluation, this excursus is dedicated to outlining the most important associated issues and subjects of debate.

Three initial rules have to be respected when discounting and establishing a discount rate:

- Non-monetizable effects may not be discountable. If such effects are included in an evaluation, it is not suggested to aggregate discounted and undiscounted criteria.
- The choice of the discount rate must be coherent with the use of nominal or real prices. Real discount rates are usually significantly lower than nominal rates.
- The discounting periods must be equal for all project alternatives. Varying discounting periods would lead to different effective rates of interest. Usually the period is one year.

In many cases, the process of how the discount rate is established will not be tackled in a project evaluation. In some cases, a seemingly appropriate discount rate may be set arbitrarily based on the requirements of private investors. For public projects, it is common practice to rely on fixed discount rates, as for example stated by Leviakangas & Lahesmaa (2002, p.278) regarding transport authorities. However, the range of these fixed rates varies between countries and even between the agencies within a country. Also, the applied discount rates have changed during the last fifty years. Boardman et al. (2006, pp.268,269) collected a series of discount rates proposed by public agencies in various English-speaking countries. A comparison between the 1970's and 80's and current guidelines finds that the suggested discount rates were then, in various cases, set to about 10 percent (real). This is higher than nowadays. At present, the US General Accounting Office, the US Congressional Budget Office and the US Environmental Protection Agency use rates between 0 and 4 percent. The British Treasury suggests a discount rate of 3,5 percent. For especially long term projects, a time-declining discount rate is proposed for effects occurring after 30 years. Evaluations for the German FITP 2003 and also for the 1992 version, apply a discount rate of 3 percent. (Birn et al. 2005b, p.35). Similarly, the Austrian RVS guidelines propose this value (FSV 2002, p.9). Discount rates used to evaluate private investments are usually higher than the ones used for public projects as they reflect the risk of individuals or small groups and also a compensation for forgoing consumption. It is therefore important to differentiate between private and social discount rates.

Generally, the approaches to establishment of the discount rates also vary depending on whether the project is of a public or private nature. For use in entrepreneurial project valuation, Loderer et al. (2010, pp.333-357) describe an approach which essentially consists of adding a risk premium to an identified risk free interest rate. To estimate the relevant components (risk free rate of return, market risk premium and project risk) the Capital Asset Pricing Model is employed. In public projects, discount rates are often based on the long time historical performance of government bonds and securities as in the case of the German FTIP and also recent figures used by US agencies (Birn et al. 2005a, p.35; Boardman et al. 2006, p.268).

However, both of the mentioned techniques derive the discounting values from market interest rates. Boardman et al. (2006, p.258) argue that this is not necessarily optimal to determine a social discount rate. The market reflects the preferences of individuals. Aside from market distortions which lead to inaccurate results, a society may have a different appreciation of future effects than an individual. Another problem is that preferences may change over time. If long term projects affect future generations, which do not participate in today's markets, this should be respected when selecting a social discount rate. The choice of a social discount rate is, in that respect, closely

associated with the issue of sustainability. A high discount rate, for example, may lead to disregarding costs occurring in future time periods. At the same time, benefits occurring to future generations would be weighted as practically worthless. Using high discount rates thus may favor less sustainable projects.

It is not possible to provide a simple answer as to which level of discounting should be used. Almansa Sáez & Calatrava Requena (2007, p.712) go as far as determining a CBA that is based on conventional discounting as obsolete for projects with significant (in this case environmental) externalities. Should discounting hence be completely refrained from? The use of a 0 percent discount rate has been supported by some of the most important economists such as A. Pigou or R. Solow, as presented in Hepburn & Koundouri (2007, pp.173-174). Some evaluations even applied the concept in practice, for example in context of waste disposal (Brunner et al. 2001). However, not discounting future effects is as debatable as discounting them. Core issues such as the principal preference of well being (or consumption) in the present instead of the future would be neglected completely.

Recent approaches propose different discount rates depending on the specific characteristics of a project. The suggestion of Moore et al. (2004, p.806) differentiates between short term projects and intragenerational[52] projects. Within these categories, the suggestions again vary depending on whether or not the public project is likely to displace private investment or not. Additionally, working with various discount rates in a single evaluation is proposed. This is aimed at declining discount rates which, e.g. drop below 1,5 percent for evaluation periods after 100 years. Other methods than the one applied here may produce even lower rates for the long term. Differentiations may also be made regarding the character of the discounted effects. Almansa Sáez & Calatrava Requena (2007) propose, in principal, a differentiation using a common discount rate for market goods and a lower rate for non-market goods, which e.g. were operationalized to be included in a CBA.

3.2.3 Analysis of value added (AVA)

A recognized term in categorizing project evaluation methods is economic impact analysis[53]. Within economic impact analyses, the contributions of a project to the economic development of a given region are of interest. In this context, the impacts on agents other than the project developer or operator and the public territorial authorities have to be taken into account. The evaluation is based on the change in final demand induced by the project. Upon this, the economic impact analysis assesses to what extent the increased economic activity affects employment and the value added. The analysis is limited to a determined region. Frequently borders of administrative regions are used to delimit the scope of the evaluation.

[52] Projects with effective impacts extending over long periods are often termed intragenerational. The threshold for this quality is not uniquely defined. In some cases effects occurring in periods after 25 years of the project initiation are viewed as intragenerational, in other cases 50 years is used.

[53] The acronym EIA is used for the economic impact analysis. However, here it will be used to refer to the environmental impact assessment. As a consequence, economic impact analysis will not be shortened.

Both value added and higher employment lead to increased income. The income generated in a region is expressed as the gross domestic product[54] (GDP). This indicator of economic development is recorded in the national accounts. The economic impact analysis is thus also linked to this system. Aside from the GDP, changes in the trade balances can be identified as well.

To assess a project's contribution to the economic development, two sets of methods are available: general equilibrium models and multiplier analysis. Within the latter, different levels of analysis exist. The highest level is to derive the multipliers from the input-output tables, based on the work of Wassily Leontief. This approach is presented here, following the description of Schönbäck & Bröthaler (2002, pp.600-611). It will be designated analysis of value added (AVA).[55]

The AVA focuses on effects from a single project aspect: the demand for goods and labor induced during establishment and operation of the project. There is no discrimination whether this demand is caused by public or by private agents' investments. The consequences of the changes in final demand are monitored in a defined region's economy. All of the values the AVA is based upon as well as its results are expressed in monetary terms. Only the employment effects are measured as either person hours or adapted to better serve for political communication, such as jobs created or safeguarded.

All of the effects that are induced by the project can be classified as either primary or secondary. Both primary and secondary effects may be of a direct or an indirect nature. Direct effects are changes in economic activity occurring in economic sectors which are providers to the project. The increased activity in these sectors again requires intermediate inputs. The effects occurring in economic sectors which are producing intermediate inputs for the providers to the project are referred to as indirect effects.

Primary effects will likely lead to an increase in income in the analyzed region. This income, the direct taxes and the savings rate deducted, is used for further consumption of households and thus changes final demand. Any direct and consequent indirect effects of the spending of additional income are categorized as secondary effects. Secondary effects are not necessarily included in the analysis. An estimate regarding their volume is provided by Hlava (1997, p.291) who quantifies them as a third of the primary effects. This estimate however may be specific to the regional economy or the project analyzed.

Calculation of the effects induced by the project is based on the interdependencies of economic sectors. Input-output tables are a representation of these interdependencies. Statistics agencies provide these models of national economies.[56] This accounting scheme is a static, deterministic

[54] The GDP is best known as an indicator at the national scale. Nonetheless it may also be calculated for a region other than a nation.

[55] This designation was established to distinguish this specific method from the less complex approaches. The literature uses generally only uses the more generic terminology: input-output analysis or economic impact analysis.

[56] The most recent set of input-output tables available for Austria is from the year 2006 and is based on the European System of Accounts 1995. (STATISTIK AUSTRIA 2010b, p.9) The US input-output models, which are calibrated at county level, are commercially available from different institutions. (G. Weisbrod & B. Weisbrod 1997, p.20)

representation of a region's economy. When analyzed, multipliers for the economic processes may be derived. Naturally, the project's final demand has to be attributed to specific economic sectors before the multipliers may be applied. Consequently, primary and secondary value added may be calculated and employment effects derived.

The results are presented in four dimensions:

- Regional production (classified by goods)
- Imports (classified by goods)
- Value added (classified by sectors of economic activity)
- Employment (person-years, full time equivalents)

Since the effects may be presented disaggregated for economic sectors, it is possible to analyze the distribution of the impacts; e.g. how large effects are within the region as compared to the imports induced by the project, or which economic sectors benefit especially from the increased activity. For public decision makers, the information generated is significant as public spending for a project may be viewed in the light of the value added in the regional economy. The indicator can be interpreted, in a way, as a social return on investment. Politicians often place the most importance on employment effects.

Additional guidance on the interpretation of analyses applying input-output multipliers is presented by G. Weisbrod & B. Weisbrod (1997, p.17). While they also see the value added as the *"most appropriate measure of impact on overall economic activity in a geographic area"*, the measurement of personal income in the region (as expressed by wages) should not be neglected. Value added may be redistributed to agents external to the region although it is generated in the region. This becomes increasingly likely due to the processes of globalization and reducing market barriers. The issue's importance grows when small regions are analyzed. Wages paid to residents of the region do not exhibit this weakness and are a more conservative indicator of regional income effects.

Whichever result of the AVA is focused on, it has to be considered that these are gross effects only. The effects and dimension of impacts of alternative projects and investment would have to be calculated separately and then compared to assess the net effects. Only by viewing the given project in reference with alternative activities is it possible to determine its superiority. The gross impact alone has a purely informative quality.

The advantage of the AVA is obviously its foundation in the statistical description of the state of the economy. Hence, problematic assumptions can be avoided to a certain extent. The statistical basis is an argument in favor of the analysis as compared to the second option in economic impact analysis. General equilibrium models normally work based on a set of hypotheses e.g. on the behavior of agents. Thus the result is strongly influenced by these assumptions which are often debatable.

At the same time, the amount of data and effort required to construct the input-output tables is very high. Thus, by the time the tables become available the state of the economy they describe is surpassed by years. Adaptation to the current state is accompanied by further problems.

Further, as the input-output model is static, future developments or changes in the interdependencies cannot be reproduced. The AVA is not a static evaluation method as it is possible to vary the magnitude of effects generated by a given project for each period. On the other hand, changes of prices due to increased demand or utilization of productive capacities remain disregarded. The same applies to eventual expansion of productive capacities. Also, multiplier analyses assume a constant under-utilization of the economy's productive capacities. General equilibrium models are, in that sense, superior since they allow the simulation of dynamic developments.

Finally, the input-output tables use mean values both in the context of economic activities and goods as well as the regional dimension. In the case of the former, the whole economy is reduced to a limited number of categories. In Austria the systematic is composed of 57 categories of goods and the same number of activities (STATISTIK AUSTRIA 2010b, p.9). The level of aggregation is the national level. Differences between sub-national regions have to be estimated based on additional information, if available. The plausibility of any further assumptions has to be well supported. It would be desirable to derive values from econometric studies of comparable projects (e.g. with spatial and temporal proximity).

Since an AVA to calculate the value added and employment effects may be applied to any private or public activity of a productive nature, its application to ITS projects is undoubtedly possible. Special attention should be directed towards the last issue discussed. Generalization is especially problematic for projects using highly specialized intermediate goods. The interrelations and values relevant for these economic activities may deviate significantly from the mean values provided for the whole sector. Inaccurate results are thus more probable.

This method does not examine economic efficiency. While it serves to analyze the contribution of a given project regarding goals in regional development and employment, the increase in welfare is not put into context of the costs. Nonmonetary effects, both positive and negative, remain excluded.

3.2.4 Fiscal impact analysis (FIA)

The FIA examines impacts a project has on a public agency's budget. Primarily, it addresses decision-makers in territorial authorities as opposed to public agencies incorporated under private law. As put forward in Table 6 (see sectors 3 and 4), it may be conducted to analyze both public and private projects alike. Especially when public authorization is required or public funding involved, the FIA will be relevant in the context of private projects. In any case, it generates answers regarding fiscal feasibility and whether the project is advantageous for a given public agency. It is normally used ex-ante.

Although in subsection 3.1.5 the subject of outsourcing evaluations was already discussed, here it seems appropriate to underline that a FIA is also not necessarily conducted by the agency whose

budget is the subject of analysis. Sometimes, this kind of analysis is required from a private project developer, or even executed on his initiative[57] (Edwards & Huddleston 2010, p.28).

Within FIA, different approaches are used, categorized into such relying on case studies and others using average multipliers (ibid., p.26). Here, the description of the method follows Schönbäck & Bröthaler (2002, pp.611-626) which is appropriate for the Austrian situation. Departing from an agency's current budget, this approach may be related to the latter group but actually goes beyond a standard FIA by including effects that change the repartition of funds through the fiscal equalization. This becomes necessary if the analysis aims to satisfy the requirements of the Austrian Federal Budget Act (BHG, §14 Sec.3) .

Three types of project effects are taken into account:

- Direct revenues and expenses of the public agency
- Value added through changes in final demand resulting in revenues from taxes and charges as well as expenses
- Changing public responsibilities or distributional schemes leading to changed intragovernmental transfers through the fiscal equalization

Calculation of the direct revenues and expenses is similar to the entrepreneurial project valuation. However, the accounting scheme used by territorial authorities follows the system of the national accounts, which differs from private accounting.

The complexity of course lies in the latter two items of the three listed above. To calculate the second item, first the value added and employment effects have to be known. They are taken from a different evaluation method; the multiplier analysis, as presented in 3.2.3. Hence, the changes in public revenues and expenses may be determined (e.g. taxes or payment of unemployment benefits) and then attributed to the respective public agencies which administer them.

Since a large share of the funds are redistributed within the public sector, especially between territorial authorities, the scheme of fiscal equalization[58] determining the actual transfers is of major importance within the FIA. In the case of municipalities, the population and the volume of the direct income achieved by the agency constitute further variables in the repartition scheme. Especially for public agencies on the municipal level, the FIA is of interest since increased direct revenues or revenues from local taxes and charges may reduce the transfers received from higher levels.

Changes in the agency budget have to be predicted both for a scenario with the project and a do-nothing situation. The FIA result is a disaggregated statement of project induced changes in

[57] A reason may be that the developer hopes for better chances of public support or authorization of his project. Naturally, a positive impact on the public agency's budget is a favorable attribute to a project. Especially FIAs developed with his background should make the assumptions chosen clear to avoid accusations of manipulation.

[58] In Austria fiscal equalization is regulated in the "Finanzausgleichsgesetz 2008 (FAG)" published in the Federal Law Gazette I No. 103/2007.

revenues from the agency's own charges, the agency's revenue shares of conjointly collected taxes and transfer payments. In theory, these figures can be aggregated to produce a statement whether the overall impact on the agency's budget is either positive or negative.

Results produced by an FIA might appear very precise, especially when using standardized *"off-the-shelf models"* (Edwards & Huddleston 2010, p.37). In that light, it is important to bear in mind which predictions, estimates and assumptions the analysis is based on.

Commonly, the FIA is applied to assess municipal land use regulation measures or real estate development projects from a municipal point of view. However, it is neither said that the FIA has to be limited to the municipal level, nor that the only practical application is for urban development projects. Technical ITS measures may be directly implemented by territorial authorities, e.g. municipalities. An FIA might be warranted or necessary in this case.

Further significance is attached to the FIA as it may be applied to satisfy legal requirements to assess the impacts of regulatory measures on federal agencies' budgets, as described in 3.1.3.

3.2.5 Cost-effectiveness analysis (CEA)

Especially in the English literature, CEA is sometimes seen as a variant of the CBA (G. Weisbrod & B. Weisbrod 1997, p.29) or as a method the use of which is receding (Lee 2000, p.44). Alternatively, it could be perceived as a mere special case of an MOA. Somewhat differently, the method is presented at a level with the CBA and the MOA in publications of the Vienna University of Technology (Schönbäck & Bröthaler 2002, p.598; Cerwenka et al. 2007, p.194). The consequent description of the method follows Boardman et al. (2006, pp.463-478) where CEA is also seen as a related but alternative method to CBA with its own qualities.

The significant difference between CBA and CEA is that while the former forces monetization of all included effects, CEA compares the internal, monetary costs of the agent developing the project with a single effectiveness measure (Boardman et al. 2006; Meyer & Miller 2001, p.506; Levin 1983 as cited in De Brucker et al. 2004, p.173) which may be measured in any dimension. This advantage is practical when it is not possible to monetize the benefit measure or, equally, in case of ethical conflicts resulting in an unwillingness to monetize an effect.

Input dimensions of the CEA are the investment costs of the project, which are the present value of capital costs and operational cost. The choice of the effectiveness measure is determined by the project's goal or, alternatively, by other policies. Since the dimensions of the two variables are different, the result can only be expressed as a ratio. While the

- cost-effectiveness ratio (cost divided by effectiveness) is commonly favored, it is naturally possible to express the effectiveness achieved by a determined cost unit as calculated in the
- effectiveness-cost ratio (effectiveness divided by cost).

The relative nature of the outcome dimension makes it practically useless by itself. Thus it can only be used to compare alternatives and establish a ranking. This is easily done when alternatives have

the same cost or, in the opposite case, when effectiveness is held constant. An example would be the selection of a project where a (policy) goal must be achieved with a given budget.

Difficulties in the ranking process may occur when the project size of the analyzed alternatives varies. In that case, it may be helpful to establish additional constraints such as minimum levels of effectiveness, units required, or a maximum acceptable cost.

In extension of the technique described so far, instead of a single effectiveness measure, costs can be contrasted with an effectiveness matrix, reflecting contributions to different goals, as implicitly proposed by the elaborations of Cerwenka et al. (2007, pp.200,206). A single effectiveness ratio is then not computable unless the effectiveness criteria are aggregated in some way. The additional information certainly adds to the quality of the evaluation but it does not necessarily make the process easier, especially in case of controversial effectiveness results. In this case, also the borders between the CEA and the MOA become unclear. The variations of MOA methods may produce the same result and additionally allow for aggregation if desired by the analyst. Thus it is found that the strength of the CEA being its simplicity should be retained by comparing one effectiveness measure against the cost.

Evaluation of ITS measures through CEA is definitely an option. It may be applied for measures where economic efficiency is not the primary consideration. Further it is a useful tool if the effects contributing to the objectives of the projects are not monetizable or monetization would be too costly in terms of time and money or is undesirable. In this light, CEA evaluations might be interesting when contrasting a project's cost with the contributions to traveler comfort, safety or the operator's public image. Also, the CEA is probably one of the less complex and therefore less costly methods. Still it may be sufficient to satisfy legal evaluation requirements as presented under 3.1.3.

3.2.6 Multi-Objective Analysis (MOA)

Usually a project affects more than one stakeholder. In most cases the interests and consequently the goals of these stakeholders vary. Also it is common that a single stakeholder has more than one goal. The evaluation methods so far presented answer the question whether a project is desirable measured against a single objective. The basic concept of the multi-objective analysis (MOA) is to extend the evaluation to determine the desirability of a project towards more than one objective.

A large variety of approaches and techniques has been developed within MOA. It is neither the objective of this text to produce a complete overview, nor would it be possible in the available space. To gain orientation, the common elements and basic tendencies of the specialized developments of techniques belonging to the group of MOA are presented. This is followed by a discussion of its potentials and shortcomings. A condensed and clear summary of how to conduct an MOA and the most important variations is provided by Cascetta (2009, pp.648-679). A list of reference notes is also included.

An MOA, in general, begins with an effect analysis. It relies on defining a set of criteria which measure the effectiveness of a project regarding the different objectives. The criteria are commonly derived from objectives determined by (or at least associated with) the identified stakeholders. The

project's performance is then measured as scores in those criteria. Consequent weighting and standardization of the criteria is possible. The performance scores in the respective criteria are used to rank alternatives, e.g. by identifying clearly dominant[59] projects. To this point a rather simple effect analysis would suffice. The actual diversity in MOA techniques has developed to aggregate the scores to a single criterion.

A common term in recent international publications is multi-criteria analysis (MCA). It is to be understood as a synonym for MOA (ibid.). However some authors also prefer MOA without mentioning MCA, see for example Meyer & Miller (2001, pp.516-523). In the present thesis, MOA is used to clearly distinguish the methods as surpassing the simple effectiveness analysis. The problem arises in the German language where "Multikriterielle Wirkungsanalyse" is at times used to describe the simple effect analysis. As the German term directly translates to MCA this may be confusing as a different concept may be but not always is implied. The concept of MOA is in some German publications (Birn et al. 2005a, p.25; Witte 1989, pp.41-49; Hampe et al. 1981) and especially Austrian literature (FSV 2010, pp.35-40; Cerwenka et al. 2007, p.194) mainly termed as "Nutzwertanalyse" [60]. Since it is assumed that many readers of this thesis are native to the German language, the term MOA is used to clearly distinguish the complex, aggregating methods from the simple effect analysis; although the latter is an inherent part of the former.

Determining the MOA's situation in relation to other evaluation methods is not an easy task since there are various possibilities. Schönbäck & Bröthaler (2002, p.598, Figure 1) perceive the MOA as a twofold process. The first step in an MOA, the effect analysis step is located prior to other methods such as the CBA, CEA or aggregating techniques of MOA[61]. The first part of an MOA serves as a common basis to the three other methods. De Brucker et al. (2004, p.173) mention that the CBA is a special case of the MOA and Tudela et al. (2006, p.415) more explicitly argue that *"[...] CBA is indeed an MCA method itself"*.[62] Since MOA may constitute a complete evaluation method up to the levels of aggregating results and comparison of project alternatives, it may also be seen at a level with the CBA or CEA (Gamper & Turcanu 2007, p.299). In contrast to the understandings described until now, it is also possible to use CBA as an input variable in a MOA. The result of the former then appears as one criterion in the latter. In the Netherlands, transportation planning uses this approach (Bristow & Nellthorp 2000, p.52) and Stevens (2004, p.107) titles this construction the third paradigm of CBA. Figure 10 illustrates three variations on how an MOA may be situated in relation to other evaluation methods, based on the presented elaborations.

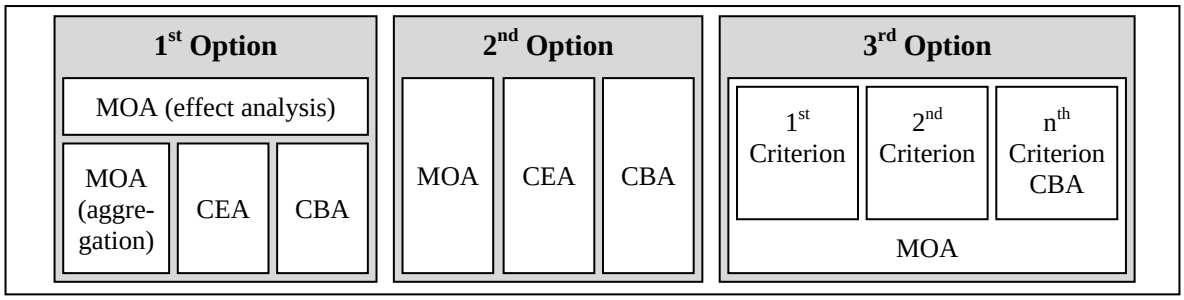
[59] Project alternatives that score at least as good, or better than any other project alternative in every criterion.

[60] A generally accepted translation of "Nutzwertanalyse" could not be found in spite of thorough research. In attempts to translate the term various English terms are strained. The most renowned publication, associated with the German FTIP, translates "Nutzwertanalyse" as "utility analysis" (Birn et al. 2005b, p.25; Birn et al. 2005a, p.25). Research found that neither the concept of utility analysis nor any of the other translations comes as close to mirroring the idea of the "Nutzwertanalyse" as the MOA. As there are several variations of MOA the "Nutzwertanalyse" may be understood as one of them.

[61] The original lists the German "Nutzwertanalyse" at this place.

[62] As previously established, MCA and MOA are synonyms.

Figure 10: Situation of MOA compared to other evaluation methods



Source: Author

However an MOA shall be applied, the method serves in general two purposes:

The first purpose is a direct analysis of project effects. In contrast to the evaluation methods described so far, there are practically no limitations on which effects may be considered. Hence, MOA is often seen as the answer to the drawbacks of CBA. Problems of monetization are avoided by establishing autonomous reference scales. These scales may assume various forms e.g. ordinal, interval or ratio scales. The criteria usually have different dimensions. The project's effects are measured as scores on these criteria scales. In MOA, it is even possible to incorporate previously qualitatively described but otherwise immeasurable effects of a project, for example by assigning a value on an (ordinal) scale. Therefore it is also possible to include subjective criteria in the evaluation[63]. The result of this first purpose of an MOA is structured information for decision-makers regarding the impact of a project in different matters[64]. Comparison of the different impacts of one project is facilitated by normalizing them to the same level of measurement. Of course, a loss of information is associated with this procedure which has to be weighed against the gain in comparability. The actual value of this structuring of information emerges when alternative projects are compared with regard to their respective contributions to the various objectives.

As a second purpose, MOA includes a large variety of methods to support decision-makers in choosing among the alternatives[65] described in the first stage. Depending on the set of projects at hand, the decision-maker's preference and also the paradigm the analyst follows, the result of the first phase of an MOA may be considered sufficient. In cases with many alternative projects, or especially controversial results in the first phase[66] further consolidation of the result may be

[63] An example used by Saaty (1980, pp.41-42) is boredom of passengers during long distance flights.

[64] Normally the impact areas are derived from political objectives. MCA is also referred to as "multi-objective analysis" because the contribution to each objective is revealed.

[65] There does not seem to be agreement regarding the terminology. Some authors describe multi-criteria decision analysis (MCDA) as the umbrella term for analyses tackling multi-criteria decision making problems(MCDM) (Belton 2002, p.1) or implicitly see MCDA and MCDM as synonymous (Mendoza & Martins 2006, p.2). Others use MCDM as the generic term for MCDA and multi objective programming (MOP) (Wiecek et al. 2008, p.337). Both De Brucker et al. (2004) and Cascetta (2009) ignore any further classification and refer to MCA in general. This latter approach is adopted here since it was found that other terms are not used coherently.

[66] Often, a project will produce controversial results. A simple example for this is a large project, which produces large benefits and therefore scores positively regarding the associated objective. On the other hand, it is likely to require large investments and hence scores badly regarding the conservation of funds objective. Without further valuation of the objectives, the normalized scores in the two criteria may neutralize each other. Many other goals also contradict each other by nature. A classic example in transportation planning is the need to choose between providing (better) access versus avoiding environmental impacts.

warranted. The literature reviewed unanimously states that the first phase of an MOA rarely produces a result where one project clearly dominates other alternatives.

Techniques with very different levels of complexity have been developed to support the second purpose in MOA. Some include direct valuation by decision makers or the participation of stakeholders to attribute weights to the objectives. Others are based on deriving weights from similar decisions. Focusing on ITS projects, De Brucker et al. (2004, pp.162-172) analyze a set of MOA techniques. Aside from basic approaches such as "summing of the scores", three more complex techniques are presented: the analytic hierarchy process (AHP), the group of ELECTRE methods and the group of PROMETHEE methods. Of these only the AHP is recommended for ITS evaluations due to the possibilities of stakeholder participation and incorporation of qualitative project effects. Also Leviakangas & Lahesmaa (2002, p.280) list the AHP as the technique of choice within MOA. All three techniques analyzed by De Brucker et al. (2004) are marked by complexity and may require significant time and effort from decision-makers, stakeholders and analysts conducting the evaluation. Further, taking into account that the ELECTRE and PROMETHEE methods do not necessarily provide complete or stringent aggregation and ranking, their use is not suggested. The use of methods of local or iterative aggregation such as multi-objective linear programming (MOLP) is also discouraged. These complex techniques analyze a non-discrete set of alternatives. De Brucker et al. (2004, p.162) assume that decisions on ITS projects usually deal with a limited number of alternatives to chose from.

Some of the MOA's potentials have already been named. They are the extension of project evaluations to non-monetizable and qualitative aspects and additionally, the option of increased stakeholder participation. The actual benefit of the latter issue lies in preventing conflicts regarding the implementation of the project. Additionally Gamper & Turcanu (2007, p.300 Table 1) emphasize that the process of establishing an MOA in cooperation with decision-makers initiates a learning process which leads to better understanding of the problem itself and consequently better decisions.

On the other hand, a set of problems contrasts these advantages. First, the selection of criteria upon which the scores of a project towards an objective are measured is a very sensitive task. Unbalanced selection results in a bias towards one or another objective and thus may favor certain projects over others. Second, harmonizing various levels of measurement creates problems itself. When all criteria are transferred to the least complex scale, a severe loss of information has to be accepted. Alternatively, if less detailed scales such as nominal or ordinal scales are transferred to higher levels of measurement, the impact of these criteria on the final result may be excessive.[67] It

[67] This is best demonstrated if a Yes/No criterion is transferred to an ordinal scale of 0-100. One option is to attribute "yes" with the value 100 and "no" with the value 0 (or reverse). Now, assume another criterion that is naturally measured in the 0-100 ordinal scale or was transferred from a higher level of measurement. The second criterion may produce scores throughout the whole bandwidth of the scale. Consequently, if the scores of the two criteria are summed up, the impact of the first criterion will be greater since it only includes extreme values.

is debatable whether this practice is at all admissible[68] but if it is applied, the result will be further distorted.

Also the weighting process by decision-makers and stakeholders may be criticized. Since it is a unique process dependent on the participating individuals and their values, the evaluation relying on it will not generate a reproducible result. This can be understood as a contradiction of scientific principles. The selection of participants also affects the evaluation result.

Finally, a difficult issue that also cannot be resolved by MOA is the prediction or estimation of project effects, which have to be described in some way before they are operationalized in the evaluation process (Gamper & Turcanu 2007, p.301).

3.2.7 Environmental Impact Analysis (EIA)

Milestones of environmental project evaluation have been its advancing legal incorporation in various countries since the 1970s. The countries of the EU have to adapt their legislation to Directive 85/337/EEC on Environmental Impact Assessments (EIA).[69] Consequently, the EIA is part of the official authorization process for a project and is only conducted ex-ante, although posterior controls are stipulated. At the same time it also includes a monitoring component. In its character of directly including a decision, the EIA exceeds the basic mandate of an evaluation (see 3.1.1). It may also be perceived as a decision-making process. As it is an evaluation at the same time, its treatment in this thesis is warranted.

Due to the legal character of the environmental authorization process, the parties are defined. The principal parties are the developer of the project and a designated body of the public administration[70]. Information has to be provided to the general public according to legal obligations and since the 2003 revision of the EU directive[71], interests of stakeholders shall also be respected as part of a participation process. In any case, the developer bears the cost of the EIA. He has to compile the information needed for the environmental impact statement [72] and also pays for consultants invited by the authority. The public authority is solely concerned with assuring the quality of the proceedings and making a decision based upon the provided information. Third parties may be heard but there is no requirement to base the decision on their views.

[68] It is however included in a manual on MOA provided by the UK Department for Communities and Local Government (2009, p.61)

[69] The European directive was last amended in 2003. Austrian law implements the regulation in the „Umweltverträglichkeitsprüfungsgesetz 2000 (UVP-G 2000)", last amended in 2009.

[70] In Austria, the designated public authorities are the Federal Ministry for Transport, Innovation and Technology (BMVIT) or the provincial governments depending on the project.

[71] Directive 2003/35/EC

[72] The environmental impact statement has to provide a description of the project, including estimates regarding the environmental impacts and possible measures of mitigation and further, the most important alternatives taken into account in the planning process.

The proceedings[73] of an EIA according to the law, as explained on the website of the Austrian Federal Environmental Agency (Umweltbundesamt 2010), exceed the simple assessment and valuation of impacts:

- The process is set in motion with the formal initiation of the EIA and submission of the environmental impact statement.
- The provided information has to be displayed to the public. Anybody may comment.
- Based on the information provided by the developer, the comments collected and other expert reports available, consultants will prepare an environmental impact expertise. Thus the findings of the initial environmental impact statement are reviewed.
- A hearing involving all formally recognized parties and the concerned authorities is to be carried out. In case of major differences, the proceedings may be suspended to allow mediation.
- The responsible authority decides on the admissibility of the project.
- Controlling of the adherence of the project to the authorized parameters is scheduled upon completion. In some cases after a period between 3 to 5 years, another inspection is necessary.

The actual processes of selecting the environmentally relevant effects, prediction of induced changes and valuation are all part of the statement provided by the developer. Often, this is outsourced to a specialized consultant.

Recent developments in the practical application, arising from the ambition to cover as many aspects as possible, lead to extremely inflated environmental impact statements. In some cases attempts are made to monetize environmental impacts in the context of the EIA (George 2010, p.20). It is to be questioned whether monetization is necessary within environmental analysis since the values there are not necessarily associated with goals of economic efficiency. Evaluation methods that do not require monetization are available; MOA for example, as presented under 3.2.6. Janssen (2001, p.101), describes the EIA practice in the Netherlands as neither requiring CBA nor making frequent use of it within the environmental analysis. The development of the environmental analysis towards a holistic assessment increasingly confronts it with problems such as serving conflicting goals or problems of aggregating a broad set of resulting variables. Eventually, this may lead to a debilitation of the environmental analysis as such and lacking concentration on the original environmental concerns. On the other hand, the tendency to view sustainability and environmental concerns in a context broader than purely ecological issues seems equally important.

As for the selection of the effects, the EIA legislation gives an idea of what should be analyzed. *"The effects of a project on the environment must be assessed in order to take account of concerns to protect human health, to contribute by means of a better environment to the quality of life, to ensure maintenance of the diversity of species and to maintain the reproductive capacity of the*

[73] In detail, Austrian regulations are being followed. Although the principles are defined at European level, national legislations have evolved slightly differing procedures.

ecosystem as a basic resource for life." (Directive 85/337/EEC) In practice, this apparently leads to the above mentioned overburdening of environmental impact statements. Consequently, the amount of information provided is often too much for decision-makers and the public it is presented to, who are not able to identify the most relevant issues. The scoping process becomes increasingly important in this context.

For the prediction and valuation of the effects, a variety of methods is available. The use of MOA and a CBA approach have been mentioned. Another option is environmental risk analysis (ERA). As Cerwenka et al. (2007, p.218) state, this is a special variation of an MOA. The ERA first quantifies the relevant impacts which are then transferred to an ordinal scale. In a next step, the sensitivity of the area subjected to influences is also located on an ordinal scale. The two indicators are then used to construct a matrix wherein the project effects may be located. If both the intensity of effect and the sensitivity of the area to this effect is also high, then the environmental risk will be determined as high. Other combinations will result in a lower risk classification.

Further, the environmental impact statement includes a socio-economic analysis to account for monetary impacts on residential population. Indicators may be changes in property values, employment opportunities and wage levels, etc. This is often conducted in the form of a regional economic impact analysis where general equilibrium economic models are used. Alternatively, multiplier analyses may also be applied[74].

The specialty of the EIA is the necessary extension of the quantitative project evaluation, the environmental impact statement, by subjecting it to public debate, the review of the evaluation by independent experts and the legal formalization of the process.

To understand the relevance of evaluation for a project's realization, it is necessary to illustrate the distinction between the actual assessment and valuation of environmental impacts and the legal process. The former, as with other project evaluations, does not necessarily predetermine the decision of the authority, and thus does not affect the realization of the project imminently. The latter, the result of the legal proceedings, does have a direct consequence for the project's implementation. In the light of an EIA that identifies significant problems and impacts that exceed the legal limits, the responsible agency can reject approval of the project. This is only the case if the important environmental effects *"cannot be prevented or reduced to a tolerable level by obligations, conditions, deadlines, other requirements, project modifications or offsetting measures"* (BMLFUW n.d., p.9, Art. 17 Sec. 5).

Which projects have to be subjected to an EIA is determined by the law. There is no differentiation between private or public projects. As defined in the UVP-G 2000, Annex 1, transportation projects proposing the construction of new freeway, highway or rail infrastructure have to be analyzed. No form of ITS is explicitly recognized in the list. In the listing of projects which only require a simplified EIA two definitions might include ITS measures. The text refers to projects leading to

[74] See also 3.2.3 for another reference to these methods.

- an extension of capacities on express roads (bordering “alpine zones” or “areas subjected to air pollution”[75] leading to usage by more than 2000 motorized vehicles per day) or
- any modification to rail lines bordering “settlement areas”[75] resulting in a capacity increase of 25% or more if the usage lies above 60 000 trains per year.

Even in these cases, it is more likely that legislators had constructional expansion projects in mind but as ITS projects may also result in increased traffic volumes[76] at an infrastructure they should not be excluded prematurely.

The nature of environmental evaluations is to determine how much a given project will harm the environment. Thus the focus lies especially on the induced negative effects of a project. Projects which are devised to have a positive effect on the environmental situation are currently not subjected to legal environmental evaluations. The same applies to projects which unintentionally induce positive environmental effects.

Although currently it is unlikely that ITS projects as such have to be subjected to an EIA, there still remains a relation. One objective of the EIA is the examination of measures that mitigate or reduce negative effects of a project, or on the other hand are able to increase the positive effects – attributes that may be related with to ITS. For example, applications which dynamically influence traffic to reduce environmental emissions may be evaluated as remediating measures in an EIA of a larger transportation project.

Developers or operators of ITS projects may be interested in an environmental evaluation to assess the positive effects of the project, independent from the formal EIA. In this case, the motivation may originate from marketing and public image related concerns. Further, an environmental evaluation could be conducted ex-post as well, fulfilling the function of evaluation methods in control of success. The cost of the environmental evaluation process, even though a lot less than necessary for compliance with the formal demands of an EIA, will have to be seen in the context of the value of the additional information or image gain the evaluation generates. These determinants will play an important role when deciding whether or not environmental evaluation which is not legally required shall be conducted.

3.2.8 Comparison of Selected Evaluation Methods

In the previous subsections several important evaluation methods were presented in a concise manner. A basic insight regarding the steps necessary to implement the respective evaluation method was provided and the advantages and drawbacks explained. For each method or group of methods a more or less extensive pool of literature is available for more details. In some cases similar methods or variations techniques within a method are compared to one another (such as CBA and CEA in Boardman et al. (2006) or MOA approaches in De Brucker et al. (2004)). Very few publications go beyond that. Cerwenka et al. (2007), as indicated, provide an overview to many different methods. Still a side by side comparison is only given for CBA, CEA and an MOA

[75] As is further defined in UVP-G 2000, Annex 2

[76] The legal text actually uses the term “capacity”. But as capacity is defined as admitted or solicited dimension of a project, “usage” is applied here in the context of ITS.

variation (ibid., p.194). A review of standardized national transport appraisal methods was conducted by Bristow & Nellthorp (2000) for 14 EU countries. However, as it focuses on the practical application it shall be drawn upon at the end of this subsection.

Primarily, a side by side comparison of the theoretical concepts of the evaluation methods shall be provided. Table 8 lists the similarities and differences of the previously presented methods. The specific characteristics are differentiated between the process and result. The potentials and limits of the respective methods are thus become apparent. The DCF is presented as a representative for the entrepreneurial valuation methods; within the MOA the techniques are not further distinguished.

Regarding some methods of project evaluation, there is relatively little discussion on their qualities or when they shall be applied. This is the case with the DCF for entrepreneurial project valuation, the FIA for the special purpose of assessing fiscal impacts on public agency budgets and also the AVA which computes project induced employment effects and value added. It is likely that this is due to the specialized objective of the method and its limitation to monetary effects only. Monetization and the associated debate are not necessary. Between the methods evaluating the functional aspects of projects, especially CBA and MOA, the discussion which method to apply is of a livelier nature. The CEA, probably due to its simpler construction, appears to be less discussed.

Based on extensive research projects, Bristow & Nellthorp (2000, p.53) conclude that: *"The most common forms of appraisal in use in the EU member states are […] CBA and […] MCA: in the four countries where MCA is used, a CBA is contained within it."* A closer look reveals that CBA is used for standardized transportation appraisal in all of the analyzed countries. However, the extent to which certain effects are incorporated varies greatly. In more than half of the countries, analysts attempt to include environmental impacts in the evaluations. Germany and Spain even attempt to monetize the value of employment effects, economic and social cohesion or regional policy[77]. The rest of the standardized evaluation frameworks limit themselves to simply measuring or, in the simplest case, qualitative assessments of effects that are difficult to measure, if they are taken into account at all (ibid., p.54). Sadly, as the study was conducted some time ago, it is likely that details have changed since (see for example footnote 77). In the US, at least at the federal level, CBA is the dominant evaluation framework (Lee 2000, p.41). The tendency of project evaluation is towards taking more and more effects into account. However, it appears that the higher the number of impacts and values which are needed for an evaluation, the more difficult it becomes to reasonably aggregate the result and to assure its quality. This may be viewed as a change favoring the MOA approach.

[77] In Germany the evaluation framework has since been adapted. A more detailed examination of the new concept is provided in subsection 3.3.1.

Table 8: Comparison of selected evaluation methods with regard to characteristics of the process and results

	Method [a]→ ↓ **Characteristics**	*DCF*	*CBA*	*AVA*	*FIA*	*CEA*	*MOA*	*EIA*
Process	treatment of effects: *monetary*	exclusively	yes	exclusively	exclusively	agency costs	transformation to non-monet. score	yes
	non-monetary	no	monetized if possible	no	no	measuremt. of effectiveness	yes	yes
	external	no	yes	yes	tax-related	yes	yes	exclusively
	indirect [b]	if cash flow is generated	yes	yes	yes	if contributes to effectiven. measure	if contributes to selected objectives	yes
	secondary [b]	no	generally no [c]	yes	yes	no	no	yes
	participation of stakeholders	no	no	no	no	no	possible	yes
	draws on results from other listed methods	no	DCF	DCF, CBA	AVA	no	incorporation of any result is possible	incorp. of MOA, AVA & CBA possible
Result	*mainly applied by decision-makers*	private	public	pubic	public	public	private and public	private and public
	aggregated	yes	yes	partial	possible	yes	possible	no
	monetary	yes [d]	yes [d]	partial	yes	no	no	no
	appropriate for single project or single alternative	yes	yes	yes	yes	no	no	yes

[a] DCF: discounted cash flow method, CBA: cost benefit analysis, AVA: analysis of value added, FIA: fiscal impact analysis CEA: cost effectiveness analysis, MOA: multi-objective analysis, EIA: environmental impact analysis.
[b] It is assumed that all project evaluations include primary direct effects in some way.
[c] Unless it is possible to measure the cascade of impacts to equal depth for costs and benefits.
[d] If NPV is calculated; (social) payback period, IRR/SRR or BCR are naturally not monetary indicators although based upon them.

Source: Author

Some authors in fact prefer the use of MOA over CBA or CEA, specifically for evaluating ITS measures. Such an argument is summarized by De Brucker et al. (2004, p.173)[78] and based on the conclusions that most effects of ITS projects are intangible and that there is little information available on the costs of ITS measures. Further reasoning is directed at the methodological deficiencies of CBA such as difficulties in predicting the user benefits or integrating distributional considerations. However, it should not be forgotten that MOA also involves significant problems. Further, a significant share of the critique issued regarding CBA is rooted in the lack of information regarding the costs of ITS. It is conceivable that with wider application of ITS, the issue will diminish. Since the statement in question was issued nearly a decade ago, it is likely that significant progress has been made. A detailed ex-ante technical feasibility and cost analysis, for example, was conducted by Janello & Bruns (2005). In any case, the argument should not be discarded completely as ITS are constantly improving and the newest technologies are being applied and hence also effects may vary.

In his review of CBA applied to ITS projects, Stevens (2004, p.106) finds that, for most evaluations conducted until that time, CBA was applied exclusively. A more state of the art approach, as he puts it, would be to also measure non-monetized effects and let that information stand beside the CBA result, Further, these measurements and the CBA could be integrated in an MOA.

In fact, as a solution to the issue whether CBA or MOA is the appropriate evaluation method, the complementary use of both methods is proposed by various authors (Peng & Beimborn 2000, p.4; Gamper & Turcanu 2007, p.299). This simple and attractive answer leads to the problem that, naturally, two evaluations take longer and are more costly than one. Certain economies of scale do exist within project evaluation. For example, the prediction or measurement of certain effects may serve both evaluation methods. Further, as demonstrated in Table 8, results or partial results of one evaluation method may serve as inputs to the next. Regarding the effort of the analyst, it has to be noted that as the evaluation process advances, very specific professional expertise is necessary. Therefore a significant increase in effort is not avoidable. Often teams of differently specialized analysts work together. Two approaches to combine various evaluation methods, even exceeding the CBA versus MOA debate, are discussed in the following section.

3.3 Complementary use of evaluation methods

The overview of evaluation methods, provided in 3.1.4, and subsection 3.2.8 on the comparative analysis of methods, has displayed that there is no single method able to integrate the full spectrum of a project's effects or answer all questions regarding a project. To provide further insights from different points of view or by taking a broader spectrum of effects into account, one solution is to apply various methods as part of one evaluation process. The following two approaches seem especially promising.

[78] Opinions were issued by Stough et al. and Shintler in: R. R. Stough (Ed.), Intelligent Transport Systems: Cases and Studies. Cheltenham: Edward Elgar 2001

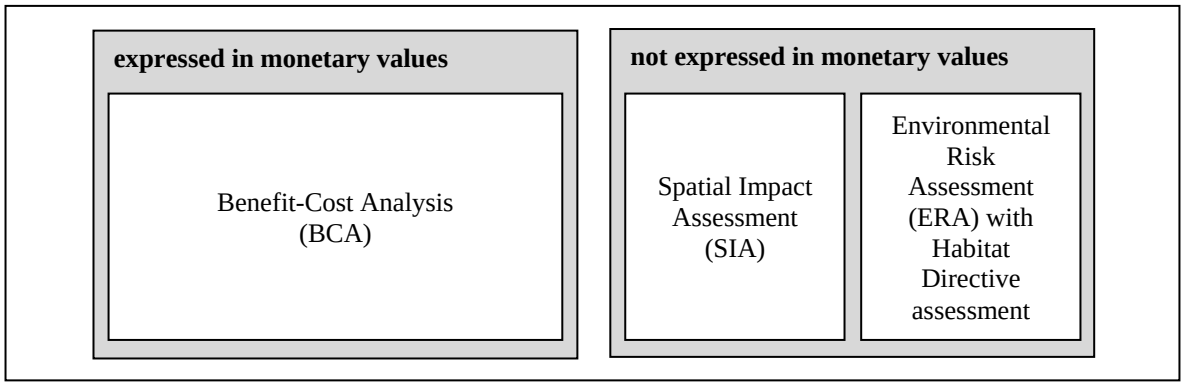
3.3.1 The macroscopic evaluation method of the Federal Transport Infrastructure Plan 2003, Germany

Germany, like other countries, establishes a document to structure public investment in federal transportation projects, the Federal Transport Infrastructure Plan (FTIP)[79]. This has been published recurrently since 1973. The core element of the plan is a listing of projects, prioritized according to the BCRs calculated in a CBA.

Construction projects to newly establish or maintain existing transportation infrastructure are the focus of the FTIP. ITS are recognized in the newest document; for example the system used to implement the heavy goods vehicle toll, the shipborne automatic information system or highway traffic control systems. However there is no surface transportation ITS project included in the priority projects listing and thus evaluated. Independent of this, the methodology established for the FTIP is also interesting in the light of evaluating ITS.

For the latest version of the FTIP, released in 2003, the evaluation methodology was modernized and considerably extended. In addition to the CBA[80], each project is now subjected to analysis from an environmental point of view and according to its coherence with urban planning and regional development goals, as presented in Figure 11.

Figure 11: Scheme of project evaluation in the German Federal Transport Infrastructure Plan



Source: BMVBW 2003, fig.1 – translation: Author

The CBA component of the FTIP 2003 evaluation method was also modernized in the revision. Specifically, the scope of the analyzed effects was extended and the monetization values were updated. Newly integrated effects are: noise outside of towns, greenhouse gases/CO_2, induced traffic and intermodal shifts. (BMVBW 2002, p.9) The latter two could be analyzed due to a sophisticated prediction model.

Some of the evaluation components which were already used in previous versions of the FTIP also deserve a closer look: employment effects and increased valuation of international traffic. Regarding the former, there is further differentiation between employment due to investment to establish the project and the project's operation. In general, the former is accounted for in a CBA by capital cost, assuming an opportunity cost of labor to society. The FTIP evaluation first calculates the project's employment effect using statistical input-output tables and then a share of

[79] German: "Bundesverkehrswegeplan (BVPW)"
[80] The FTIP uses the term Benefit-Cost Analysis (BCA).

the effect is attributed to people who would otherwise be unemployed[81]. (Birn et al. 2005b, pp.75-79) Thus, there is no opportunity cost and the employment effect can be seen as a contribution to the project's benefits to society.

The latter of the two employment effects is attributed to the accessibility increasing effect of the operation of a transportation project which is assumed to have a positive effect on a region's economy and factor mobility.[82] Consequently, an effect on structural underemployment is assumed, and calculated specifically for the regions affected by the project. For the federal perspective, only the net effect is considered, excluding jobs shifted between regions. (ibid., pp.79-83)

An extra bonus of up to 10% (depending on the share of international traffic) increases the travel cost savings for any projects serving international transportation, independent of the geographic location. This feature of the FTIP evaluation reflects benefits gained from interrelated European national economies making better use of comparative advantages. (ibid., p.83f.) This is a practical but debatable approach since it is an arbitrary positive valuation of international travel, the true benefits of which would be difficult to measure or predict.

Aside from these distinctive features of the FTIP 2003 CBA, the actual interest lies in the combination of CBA and the environmental and spatial evaluation components. An overview of the effects taken into account in the CBA reveals that a set of important environmental factors are already quantified and monetized by using damage or avoidance costs. Equally, effects in urban and regional development are accounted for. This follows the basic concept of the FTIP evaluation to account for any monetizable effect in CBA, irrespective of its affiliation with a certain field. The other components focus on non-monetizable effects and further, the purpose of the other evaluations is different. They analyze environmental risk independent of the welfare benefits of the project or, in case of the SIA, evaluate coherence with policy goals. While within the CBA, according to the method, double counting is prevented, it is accepted that some benefit and cost flows, which are already accounted for in CBA, are also integrated in the SIA/ERA evaluations. (ibid., p.23)

A brief schematic of an ERA is described in 3.2.7. The FTIP 2003 ERA follows the same principles. Its goal is to provide insight into the intensity of environmental conflicts a project might incur and supplement a general project risk analysis. The less complicated FTIP 2003 Habitat Directive assessment is exclusively dedicated to rating a project based on its impact on Natura 2000 sites[83]. Here, the distinction has to be made clear that neither the ERA nor the Habitat Directive assessment in the FTIP 2003 constitute formal environmental examinations. EIA or the Habitats Directive compatibility assessment, which are necessary for regulatory approval of a project, will have to be conducted for each project individually during its implementation process and are not part of the FTIP.

[81] The function of attribution was revised with the FTIP 2003 and now uses by far reduced values.
[82] Also this part of the CBA was subjected to significant change since the FTIP 1992.
[83] Natura 2000 sites form a network of areas protected by European law. The underlying documents are Council Directive 92/43/EEC (generally referred to as "Habitat Directive") and Council Directive 2009/147/EC (generally referred to as "Birds Directive"). The term "Habitat Directive assessment" used in the FTIP 2003 is misleading because both directives are actually respected.

The purpose of the SIA, as described by Birn et al. (2005b, pp.53-67), is to determine a project's contribution to two goals, the first of which is the equality of regional infrastructure provision. To this end, accessibility gains on links that are important for regional development are quantified and cross-linked with the state of development in a region. The second goal addresses relief of negative transportation effects on both the interregional level, through modal shifts towards more sustainable modes, and the local (urban) level through route changes. Each of the contributions to the second goal is determined by an independent evaluation process. The SIA is thus made up of three results. The significance of each is expressed through rating on a five step ordinal scale. A qualitative, verbal statement further accompanies the local relief aspect. The concluding result of the SIA is also depicted on a five step ordinal scale. Its value equals the highest score a given project has achieved in any of the contribution to urban planning and regional development goals.

As for treatment of the results of the three major FTIP 2003 evaluation components, an earlier proposal envisioned aggregation of the CBA result with the ERA result by converting them to the same (at least interval) scale which would then allow addition of values. (BMVBW 2002, p.58ff.) Finally a different approach was adopted, which is described in Birn et al. (2005b, p.68) and is summarized as follows:

Prioritization of projects is exclusively based on the BCR. Projects with a BCR < 1 are excluded. Projects with a high BCR ranking are attributed "Urgent Need" until the budget constraint is met; all others are designated "Further Need". Urgent Need projects in road construction with an outstanding SIA ranking receive funds from a special funding pool. In case the FTIP 2003 environmental analyses discovered a very high environmental risk or unavoidable significant adverse impacts on Natura 2000 sites, this is recorded with the project and instructions for further planning activities are provided, e.g. a recommendation to conduct a Strategic Environmental Assessment.

The FTIP 2003 evaluation demonstrates one option of how to account for effects that exceed economic aspects. The independent treatment of the respective results allows the recurring integration of effects, for example monetizable environmental effects can be taken into account in the analysis of economic efficiency without exempting them from the environmental analysis which would leave the latter only partially completed. Of course, as was mentioned, it would also be possible to further aggregate the results. One option, a bonus system, was already used to establish the project ranking in the 1992 FTIP. Another possibility is to use an evaluation result to further exclude projects, e.g. the Habitat Directive assessment. In the given case however, projects are only roughly defined and remediating measures were knowingly excluded. Consequently, there is potential for amelioration and any exclusion would be premature.

To what extent correct aggregation can be done depends on the integration of effects in the preceding steps; double counting should be avoided. Aside from this technical limitation (which may be overcome by adapting the design of the overall methodology) the benefits of informational consolidation have to be weighed against loss of detail as described with the MOA method in subsection 3.2.6.

The strengths of the FTIP 2003 project evaluation certainly lie in the advanced prediction method based on modeling and the resulting possibility to quantify various complex effects. The CBA alone already provides interesting approaches due to the large variety of effects treated. In a critique of the FTIP 2003 Willeke (2003, p.527) points out that complementing the CBA with results from the ERA and SIA is not beneficial for the purpose of supporting decision-makers. Instead, the methods applied in the ERA and SIA predetermine the decision by placing an overrated value on environmental and urban and regional development issues. This critique has to be put into context: the basic assumption of the argument is that only the social efficiency criterion should determine the valuation of the projects. The fact that the FTIP 2003's evaluation methods are not integrated, and the ERA/SIA results do not technically determine the ranking of the projects, marginalizes the argument to a certain extent. In case the actual problem is the overburdening of decision makers, the correct approach would be to suggest an MOA approach. There weights would be attached to the respective criteria, depending on the values of decision makers.

An inspiration for debate surely is the dimension of the FTIP 2003 evaluation. The huge number of projects to rate (submitted road construction projects amounted to about 1800 (Birn et al. 2005b, p.42)) gives cause for speculation on how accurately the distinctive situation of each project could be assessed or reproduced in the model. The consequent need to generalize is also an issue. When thinking about applying the method to a single project outside the context of the FTIP, components of the evaluation shouldn't be transferred blindly.

In addition to the information on how the evaluation results are utilized, the approach to address modal shifts and changes in route choices in the SIA instead of CBA is interesting. Those effects are also associated with ITS.

The effects taken into account in the FTIP 2003 ERA are based, according to the projects to be analyzed, on the landscape and habitat destruction of infrastructure construction. It is doubtful, that the exact concept would prove useful when evaluating ITS, where these effects are often small or do not occur at all.

3.3.2 Hierarchical economic analysis

The hierarchical economic analysis[84] was first applied to evaluate a project aimed at the completion of the A9 freeway in Austria by Schönbäck et al. (1990). The term hierarchical economic analysis describes the concept of gradually applying various methods of economic project evaluation so that they complement one another. All of the evaluation methods classified under economic evaluation in Figure 9 may be included; however, in practice, one or the other is regularly excluded. Also,

[84] The original German term is "Hierarchische Wirtschaftlichkeitsanalyse". Translation, which is not confused with any of the other evaluation methods in existence, is problematic. In the translated abstract, of the text by Schoenbäck et al. the method is titled hierarchical cost-effectiveness analysis. With the approval of Prof. Schönbäck, this translation is not adopted here in order to clearly distinguish the method at hand from the CEA as the concepts are very different.
Also the hierarchical economic analysis is not to be confused with the analytic hierarchy process (AHP), a technique used within MOA.

simplified versions of the methods are sometimes used to reduce the extensive workload associated with a full application of each method.

So far, different applications of the hierarchical economic analysis have appeared. One was the evaluation of enhancing thermal insulation of buildings by the Institute of Public Finance and Infrastructure Policy at the Vienna University of Technology (Kosz et al. 1996). The CBA of four alternative scenarios for the Austrian Danube area to the southeast of Vienna by Schönbäck et al. (1997) is complemented by further analyses by Hlava (1997). The conjointly published evaluations may also be understood as a hierarchical economic analysis. The method's applicability towards evaluating organic farming was contemplated by Kratochvil & Kaliski (2003). Whereas the basic idea remains the same, the concept was significantly modified in this case. Finally, although neither the German term of the hierarchical economic analysis nor any other indication to this integrated concept is mentioned, Schott (2004) evaluates a proposed ITS in a way comparable to the presently described framework. This case is analyzed more closely in section 4.2. These examples allow conclusions on the versatility of the method.

The entrepreneurial project valuation and especially the CBA are the dominant components in the hierarchical economic analysis. In case important non-monetizable effects exist, it may be complemented by a CEA or MOA. The mentioned thermal insulation evaluation for example includes a CEA based on the measure's contribution to satisfy political goals. All further aspects are treated consequently. Aside from the analysis of employment effects which is frequently included, some cases also examine the impacts on the budgets of territorial agencies, for example through FIA.

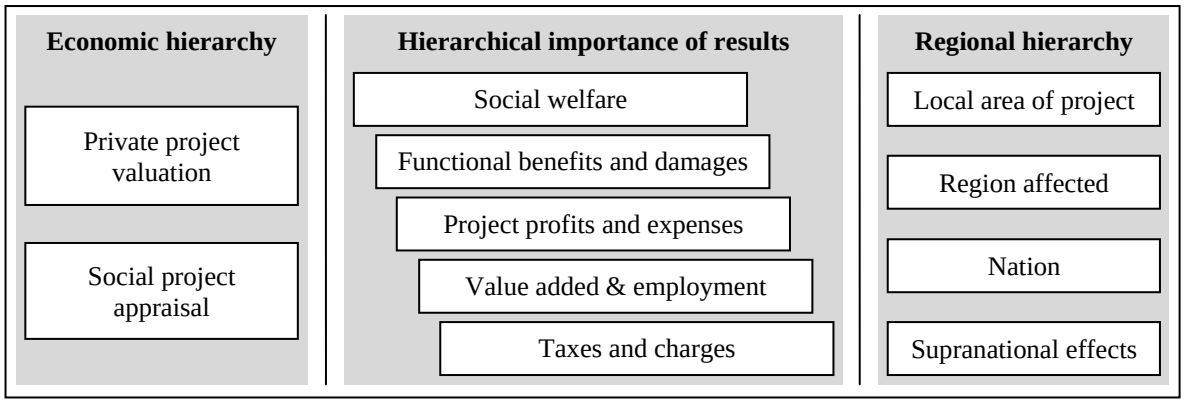
The aim of the hierarchical economic analysis is to answer two questions within the same evaluation process:

- Is it presumable that the project may be realized by a private agent, and if not, which level of subsidy is necessary?
- Is the project desirable from a societal point of view?

To this end, the hierarchical economic analysis shall provide a more comprehensive representation of the monetary and monetizable effects of a measure, without having to neglect certain aspects due to calculatory principles, as is always necessary in the case of a single method. As listed in Table 9, external effects, excluded in the private sector analysis, are taken into account in the CBA. On the other hand, transfers are included in the private sector analysis, the FIA and the AVA. Thus a very complete evaluation of a project is possible.

In coherence with the principal objective, Kosz et al. (1996, p.3) relate the term "hierarchical" to the sequence of firstly conducting an analysis on the private level and secondly evaluating the overall societal effects. Yet this is not the only interpretation. The results thus may also be viewed as a cascade of information departing from the socially most important criterion. Finally, it may also be related to the consequent increase of the geographical scale, as for example practiced in the indicated evaluation of the A9 freeway (see also Table 9). An illustrative comparison of these three understandings is provided in Figure 12.

Figure 12: Analytical Levels as Hierarchies in the Hierarchical Economic Analysis



Source: Author

Table 9: Levels of Analysis and Methods in the Hierarchical Economic Analysis applied for the A9 Freeway Completion

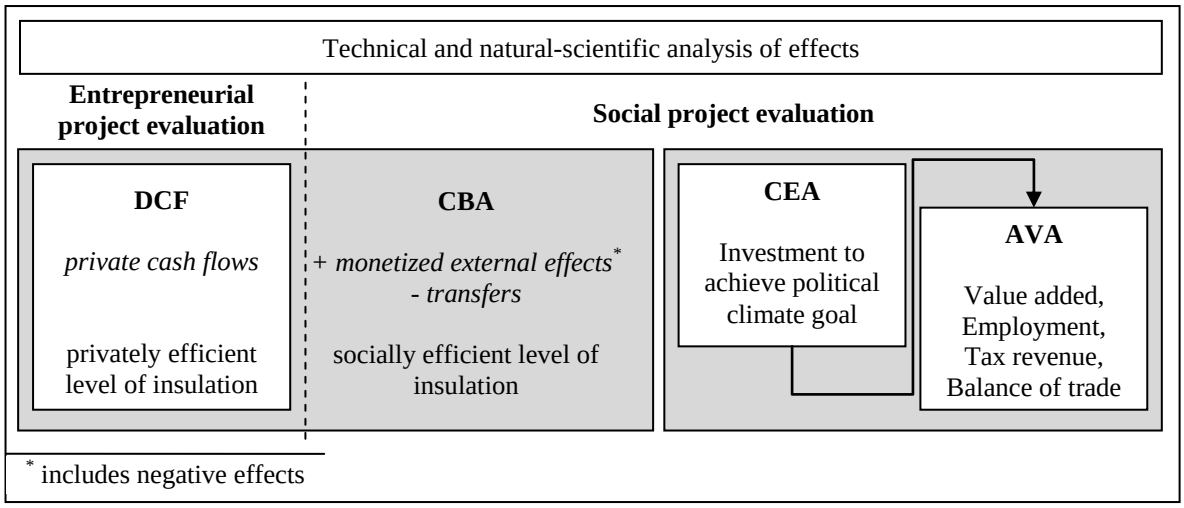
Scope of analysis	*Method*	*Effects included* [a]	*Effects excluded* [a,b]
Project locality	DCF	internal cash flows	external, non-monetary
Region affected	AVA (regional)	increase of income changes in employment	non monetary
Nation	AVA (national)	as above	as above
	FIA	monetary on public budget	all other
	CBA	real internal + external monetary + monetizable	pecuniary, real foreign non-monetizable transfers
(Supranational	CBA	as above + foreign	as above – foreign)

[a] following the categorization in 2.3.2
[b] excluded for all: intangibles, system external

Source: Author, based on Schönbäck et al. 1990, p.137, Figure 2

The approach of Kosz et al. (1996) of how to integrate the CEA shall also be demonstrated. This configuration of the hierarchical economic analysis is illustrated in Figure 13. By comparing the results of the private sector analysis and the social CBA, the discrepancy between the privately and the socially efficient level of investment is derived. Independent of the previous steps, the necessary level of investment to achieve a politically set goal is calculated. To this end, a CEA with the required effectiveness measure being constant is adapted. Consequently the computed level of investment is analyzed with respect to its income and tax effects. Although the relations between the components are of a different kind here, the key methods do not change.

Figure 13: Variation of the Hierarchical Economic Analysis



Source: Author, based on Kosz et al. 1996, p.6, Abbildung 1.1-2

As elaborated, the results of the components each answer different questions. The results are specific to the component methods and are not aggregated further. In some cases they may even be controversial. Decision makers will then have to decide upon which aspect they place more importance (Schönbäck et al. 1997, p.284).

The applicability of the hierarchical economic analysis to an ITS project is undoubtedly possible and reasonable. As this evaluation framework answers fundamental questions about the way a project may be implemented, it is likely to be applied in the early stages of project development. However if a detailed and comprehensive analysis is required, it is just as suitable to evaluate proposals where the development process has already advanced or in an ex-post evaluation.

Some authors, such as Gillen et al as cited by Newman-Askins et al. (2003, p.4) find that ITS projects are not large enough to justify the effort of a comprehensive economic analysis. They even support that analysis of distributional issues may be adequately addressed in a MOA or a CBA. After the examination of those methods as part of this thesis, it is found that at least the latter point made by Gillen et al should be viewed critically. Especially for CBA, no technique seems to be available to adequately incorporate distributional issues and MOA is by nature influenced by the values as assumed for or stated by selected stakeholders. The combination of methods in the hierarchical economic analysis is able to provide significantly more clarity on where monetary effects occur. Hence, if feasible, there are good reasons for its application.

4 Review of Conducted Project Evaluations

4.1 CBA of a freeway traffic management system: The appraisal of the corridor control system (CCS) in Tyrol by Kummer & Nagl

4.1.1 Description of the project subjected to evaluation and outline of the evaluation

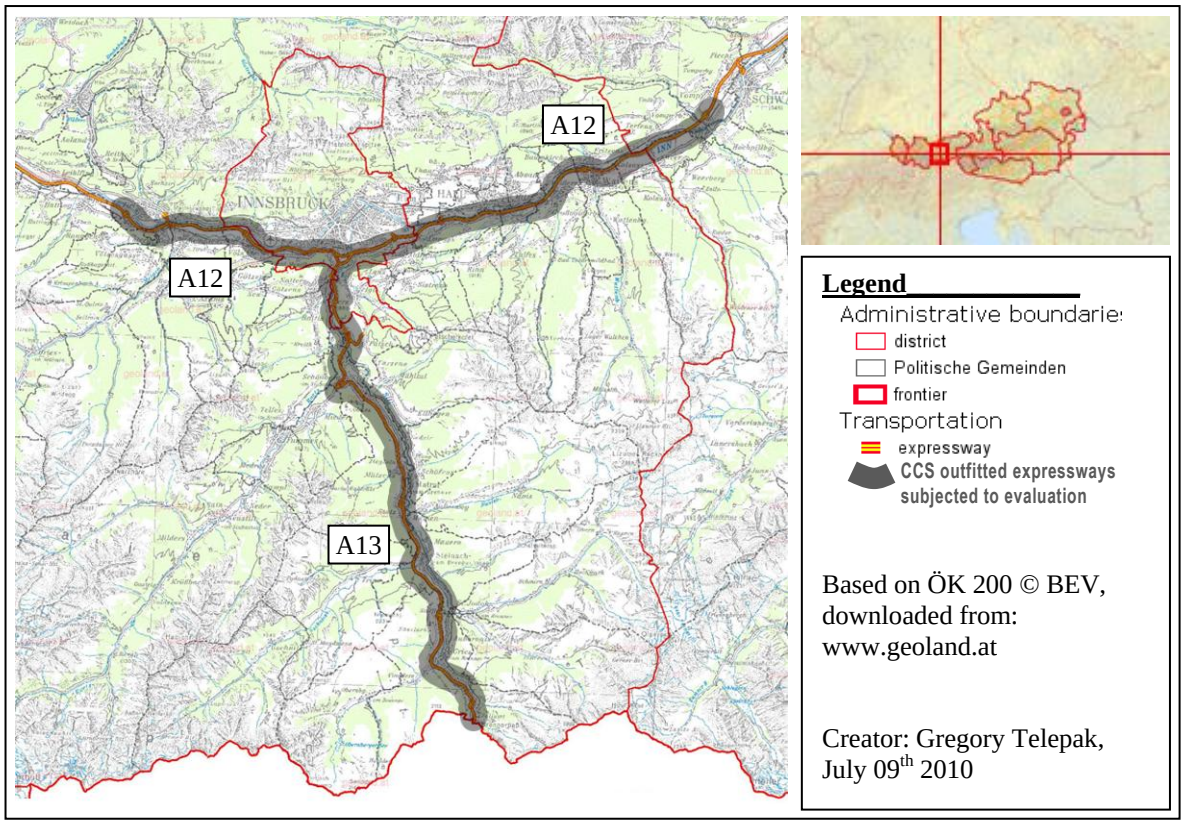
The evaluated ITS project is a traffic management system[85] installed on freeway sections in the Austrian province of Tyrol. The traffic management system was designed to provide three functionalities: first, ramp metering at highly congested freeway access points, second, variable route guidance via dynamic message signs and third, corridor control. Ramp metering affects the system nodes and route guidance intends to manage utilization of capacities of larger segments of the transportation network by redistribution of traffic flows. The CCS intends to influence user behavior on specific links of the system. Of the three functionalities, the CCS is the most extensive in terms of freeway coverage in the case of the Tyrolian traffic management system. At the time of evaluation it extended on about 68 Kilometers on the freeways A12 (Inntal freeway) and A13 (Brenner freeway). While the full length of the A13 between the junction with the A12 at Innsbruck to the Brenner Pass is covered, on the A 12 only the part of the freeway between the towns Vomp and Zirl is outfitted with CSS (Rechnungshof 2009, p.171) as illustrated in Figure 14. A few years after the traffic management system was commissioned, it was reconfigured to also autonomously react to environmental conditions and influence traffic according to the severity of environmental stress. Of the three initial functionalities only the effects of the CCS is evaluated (Nagl et al. 2008, p.134). Also, the evaluation was conducted before the environmental traffic management system was commissioned.

The system at hand is integrated with the ASFINAG traffic management information system. The most important system components are sensors and installations for traffic surveillance, components of data processing and transfer, and the traffic management center (ASFINAG 2007, p.12). In the case of the CCS, information is related to transportation system users via dynamic message signs. Examples are illustrated in Figure 15 and Figure 16. These collective on-trip traveler information systems may operate automatically but also can be manipulated from the traffic management center. Additionally, information may be sent to vehicle based components such as navigation systems which then display the messages to drivers.

Functionalities of a CCS include variable speed limits, restrictions on passing, lane management (e.g. opening of emergency lanes or closures of lanes where incidents occurred) and warnings regarding weather related dangers or construction, congestion or incidents ahead (ASFINAG 2007, p.13). In addition to demand management, a CCS may also play an important role in incident prevention and response.

[85] The ASFINAG synonymously uses traffic guidance system (TGS) or traffic control system (ASFINAG 2006, p.45; ASFINAG 2008, p.71).

Figure 14: Location of the CSS at the A12 and A13 freeways in Tyrol



Source: Author

Although meanwhile many similar systems are currently in operation on Austrian freeways, the project presented here is prominent in two ways. First, the freeways outfitted with ITS are part of one of the most important European transportation routes. Second, the ITS measure implemented was the first CCS in Austria at the time it was commissioned in April 2005 (Government of the Province of Tyrol 2009). This situation makes the project special as it has a signaling effect.

The ITS project was developed and is operated by the ASFINAG. It was also the ASFINAG which ordered the evaluation of the project. The evaluation was conducted by S. Kummer & P. Nagl at the Institute for Transport and Logistics Management of the Vienna University of Economics and Business (WU-Wien). Hence it can be assumed that the evaluation was conducted independently and with a high level of expertise. An element of caution should be retained however, as the evaluation was contract work for the operator of the ITS which may have an interest in a positive result.

This review of the evaluation of the CCS Tyrol is based primarily on a joint journal publication by the authors of the evaluation and ASFINAG staff (Nagl et al. 2008). Additionally, the official report on the revision of the ASFINAG freeway telematics program as a whole by the Austrian Federal Court of Audit is available (Rechnungshof 2009). It was not possible to gain access to the original report of the evaluation as prepared by Kummer & Nagl (2007) as the analysts were not authorized to redistribute it and the contracting institution was reluctant to provide the document. Further research revealed the existence of a more extensive document treating the issue, created by the Austrian Federal Court of Audit as part of the revision. It was equally not accessible as it contains information on internal matters and will only be distributed to ministries and certified

bodies. The published report which is also the version available to delegates of the parliament would have to suffice (Rechnungshof staff member 2010).

Figure 15: Variable speed limitation as part of the CCS at the A12 freeway in Tyrol

Source: ASFINAG 2007, fig.3-4 (section of original image)

Figure 16: Dynamic message sign as part of the traffic management system at the A12 freeway in Tyrol

Source: ASFINAG 2007, fig.3-15 (section of original image)

4.1.2 Scope of the analysis, stakeholders and effects included

The scope of the evaluation is, in a spatial sense, limited to the effects following the outfitting of roughly 68 kilometers of road with ITS components and their operation. In the temporal dimension, measurements of traffic were made over a period of four years: three years before and one year after the installation of the CCS. The evaluation of the CCS was principally intended as an ex-post analysis. In addition to this scheme, a future scenario was calculated based on extrapolations of the available figures and assumptions on further effects. Additionally, the measured and extrapolated effects are complemented with estimates regarding effects of added functionalities which until now are only planned. The time frame was set to a period of 25 years, from 2005 to 2030. In essence, this means that an ex-ante evaluation was also conducted.

With regard to stakeholders, the situation is not complicated. The ASFINAG is in charge of both freeway construction and maintenance and further adopts the role of conceiving, installing and operating the ITS. Thus only one actor has to be taken into account as developer/operator in the sense of the description in subsection 2.2.1. All other stakeholders are categorized in three groups designated users (Nagl et al. 2008, p.132):

- Primary users are freeway users addressed by the information provided through the CCS.
- Secondary users benefit from more accurate data on traffic flows and volumes measured by the traffic management system.
- Tertiary users are those non-stakeholders who realize benefits without directly interacting with any part of the ITS.

A large variety of potential effects of a CCS is discussed in the journal article by Nagl et al. (2008, pp.134-137). However not all of these effects were measured for the evaluation. Table 10 provides an overview of the measures used to quantify the effects. It further attempts to associate the effects to the stakeholder groups although this is not explicitly contained in the available documentation. Generally, the effects may be arranged into four groups: internal cost and benefits of the operator, reduced accidents and associated costs, changes in travel time, vehicle operation costs and emissions.

The internal effects occurring to the operator include the common items. Further, revenues from selling data gathered by the ITS and delayed expenses on interest rates for capital necessary to finance construction projects for road expansion are perceived as internal benefits.

It is recognized that the most important objective for the CCS in this specific case was the reduction of accidents and associated casualties. A part of the ASFINAG's annual report in 2005 is dedicated to describing the effectiveness of the Tyrol CCS. According to the report, collisions at road sections where congestion forms, follow up accidents and accidents associated with motorists driving against the traffic direction, could be avoided completely (ASFINAG 2006, p.45). A study of the project induced changes in accident numbers and type was conducted by an external consortium which produced relevant input data for the evaluation.

Travel time effects are traced back to stabilizations of the traffic flow (whereby traffic jams may be avoided) and the higher speed limits in off peak hours due to removal of static speed restrictions. *"At construction sites, the motorway maintenance personnel was efficiently supported by the TGS* [CCS] *and optimisation in traffic flow could be achieved before and after the construction site."* (sic.) (ibid.)

As for vehicle operation cost, it is assumed that the CCS can only influence time dependent variables, hence they are also related with the travel time changes. Operation costs related to travel distance are omitted from the analysis since it is assumed that there will not be changes. No operational cost is attributed to vehicles on non commercial or work trips. Here it is assumed that there would be alternative, better usage opportunities. Fuel consumption is calculated independently from the vehicle operation costs.

Table 10: Tyrol CCS - account of effects included in the evaluation

Measures of effects		*Natural dimension*	*Monetary value per unit*	*Occurrence*[a]
Depreciation for wear Capital cost Operational cost Saved expenses on interests due to delayed infrastructure construction		monetary	-	operator [b]
Change in accident fatalities		persons	2 513 759,00 €	primary users and society
Change in severe casualties		persons	281 073,00 €	
Change in light casualties		persons	20 194,00 €	
Change in accidents causing material damage		accidents	5 763,00 €	
Changed travel time work trips		person hrs.	28,00 €	primary users
Changed travel time commuter trips		person hrs.	10,00 €	
Changed travel time other trips		person hrs.	7,50 €	
Changed travel time buses	local	person hrs.[c]	19,32 €	
	long distance	person hrs.[c]	21,03 €	
Changed travel time trucks	local	composite value [d]	17,00 €	
	long distance		21,12 €	
Changed time spent in congestion		person hrs.	unknown	
Change in time dependent operation cost for commercial vehicles and work trips	car	vehicle hrs.	0,96 €	primary users
	bus local		9,70 €	
	bus long distance		17,20 €	
	truck local		8,61 €	
	truck long distance		13,02 €	
Change in fuel consumed		kilograms	0,60 €	primary user
Change in CO emissions		metric tons	3,96 €	tertiary users
Change in HC emissions			1 881,42 €	
Changein NO_x emissions			831,71 €	
Change in SO_2 emissions			356,45 €	
Change in particle emissions			317,20 €	
Change in CO_2 emissions			99,19 €	

[a] According to the categorization as described by Nagl et al. (2008, p.131 f.)
[b] Operator of ITS = operator and developer of roadway infrastructure
[c] Includes time of driver
[d] Includes time of driver and transported goods

Source: Author based on the information provided in Nagl et al. 2008, pp.134-137

Operations and fuel cost are internal costs occurring to the transportation system user, as shown in Table 10. They may be perceived as intrinsically monetary. In the evaluation, they are derived from the operation times and fuel amounts, each with physical natural dimensions. Consequently, mean values are applied. It seems this was the easiest way to calculate the overall effect for the whole group of primary users. The offsetting effects of increased fuel consumption due to higher speeds possible as a consequence of the annulations of low static speed limits and fuel saved in congestion avoided have to be balanced.

As noise emissions are neglected in the given case, calculation of the changes in emissions is ony associated with fuel consumption. The contradicting environmental effects have to be balanced here. As the emission induced traffic management system had not been commissioned at the time of the evaluation, its effects are not measured; neither for the one year calculation nor for the 25 year analysis.

4.1.3 Evaluation method chosen and description of the valuation approach

The initial assumptions of the Tyrol CCS evaluation were that the majority of benefits produced by such an ITS would occur as external to the operators calculation. Further it was suspected that internalization would be possible only for a small share of the effects, if at all (Nagl et al. 2008, p.130). The authors of the evaluation propose that the CCS service for primary users shows characteristics of public goods. A consequence of externalities and non-excludability/non-rivalry of consumption is an undersupply of socially desirable goods which is a reason for public intervention, e.g. in the form of subsidies or public provision of the good. A stand-alone entrepreneurial project valuation hence appears redundant.

Based on the available information it may be concluded that the ex-post evaluation's main objectives is to determine whether the involvement of public funds through the ASFINAG is justified. Therefore the extent of societal, external benefits and their magnitude in comparable monetary terms shall be contrasted against the internal costs and benefits of the agency. The method of choice was accordingly the CBA (Nagl et al. 2008, p.130), as described under subsection 3.2.2. Based on the result, an answer regarding the social desirability of the services provided by a CCS is possible. The possibility to measure actual changes in traffic flows provides a higher robustness to the result than estimative predictions on effects. The ex-ante analysis may indicate whether the future public investments in the given project, as well as comparable projects, are worthwhile form a societal point of view.

The evaluation was conducted in two steps:

- First, effects are compared for one period. This static evaluation compares a mean year before inauguration of the CCS and the first year of operation. The former serves as the base case while the latter constitutes the exclusive project alternative analyzed[86]. The effects are represented in one matrix, the monetary values for each effect unit in another. Consequently the monetary values for each effect can be calculated and compared.
- Second, a dynamic evaluation is done for 25 periods, equaling one year each. Therefore assumptions regarding changes of the effects over time are made. Road safety effects are assumed to remain constant. Other social benefits are assumed to increase at a rate of 1% p.a. Further, it is assumed that CCS components have to be replaced at regular intervals. The cost of these replacements is assumed to increase by 2% each year.

All of the values used for monetization are standardized to 2005 prices, both in the static and the dynamic calculation. Except for a few items, the system of monetization follows the RVS guidelines[87]. Since the RVS was to be revised, the analysts adapted the values (Nagl et al. 2008, p.134). However, in comparison with the RVS values (FSV 2002, p.10) where prices are based in the year 2000, the values in some points vary considerably. Also the structure used for the Tyrol CCS evaluation includes stronger differentiation regarding accident severity or the measures of time and operational effort. In some cases, such as operational costs, other dimensions are used for the indicators. A higher resemblance of the values and structure of the measures used may be found

[86] Comparative evaluation of various project alternatives is inherent in ex-ante analysis where a choice for one or another has to be made.

[87] The relevant document referred to in the evaluation was the RVS 2.22 (FSV 2002).

when comparing the Tyrol CCS evaluation to the revised Version of the RVS guidelines (FSV 2010), which is however not officially published to this date. The actual values used for the evaluation are listed along with the account of effects and the measurement indicators in Table 10.

None of the available documents regarding the evaluation of the Tyrol CCS, contains any reference to discounting of future monetary values. Subsection 4.1.4 will show that the result of the ex-post analysis is only expressed for a single period. In this case, discounting is not suitable. However, for the 25 period ex-ante evaluation it remains unclear whether or not future effects were discounted. Two reasons maybe envisioned: One may be that the authors assumed a standard value, e.g. 3 percent, and thus felt it was not necessary to further elaborate the choice. The problem in this case is that there is significant debate on which standard discount rate to use, as indicated in the "Excursus on the choice of a discount rate" in chapter 3. On the other hand, the lack of any reference may indicate that future values were not discounted. In other terms, this implies a discount rate of zero percent which means a high appreciation for future effects. While some experts would discard this approach as unacceptable, others use similar methods to demonstrate the importance of future actions in the light of sustainability. However, discount rates are mostly set to zero in the context of effects occurring in the far future or environmentally highly relevant effects. Neither is the case in the evaluation of the Tyrol CCS.

A sensitivity analysis complements the CBA. The sensitivity testing follows the principle of modulating the input figures and assumptions. Within the magnitude of effects the number of accidents prevented and the internal benefits of the operator were subjected to modulation. Monetization values were changed for fuel, vehicle operations and emission costs. Finally, the growth rate of external benefits was set to zero and the growth rate of operational costs increased.

4.1.4 Description of results

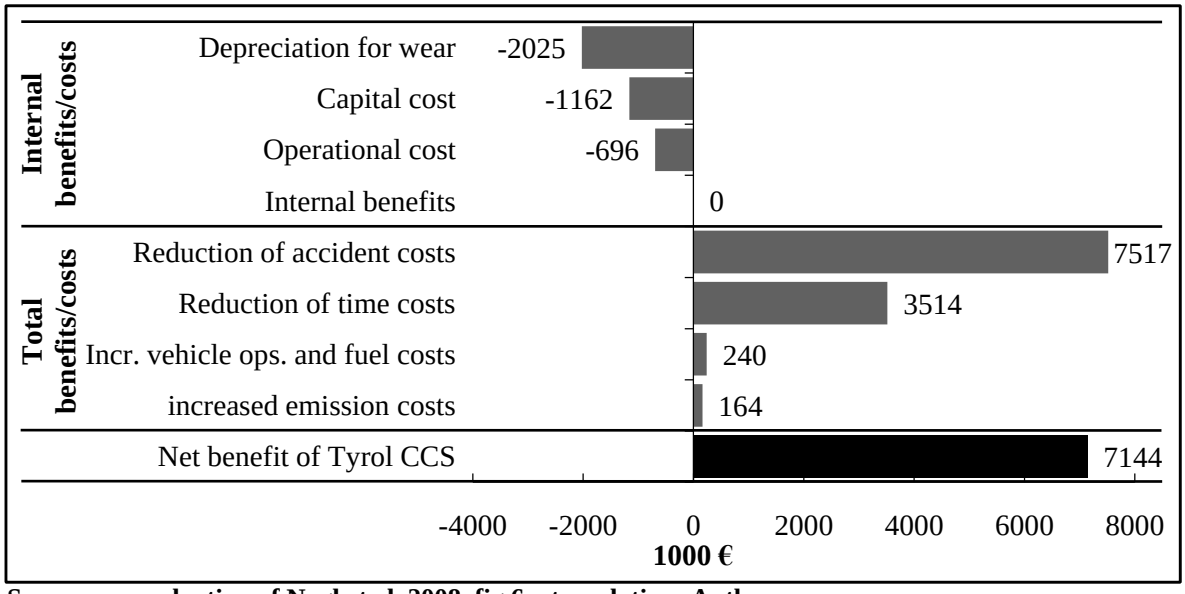
As the evaluation was conducted in two steps, statically and dynamically, the results have to be presented accordingly.

For the static approach the one-period net benefit is presented as well as a disaggregated overview of the components structured according to the effects. The social net value of the first year of operations is 7,1 million Euros. For a reproduction of the figure presented by the authors of the analysis, see Figure 17. This indicates that the project is socially desirable, regarding the effects incorporated.

The dynamic calculation of monetized effects over 25 years is presented, as previously, disaggregated for the effects (see Figure 18). The total internal and external costs and benefits amount to an overall net benefit of over 150 million Euros. The choice to present the result in this way is rather unusual. Additionally the BCR is calculated. Here the sum of the positive and negative benefits, both internal and external to the operator, is divided by the sum of the internal cost. The resulting ratio is 3,17. Hence, also over 25 periods, the evaluation finds the project to be a very good investment from the societal point of view. An indicator of incentives for private investment may be provided by balancing only the internal effects. Here it becomes clear that public intervention is necessary (assuming the given business case) as the internal costs by far

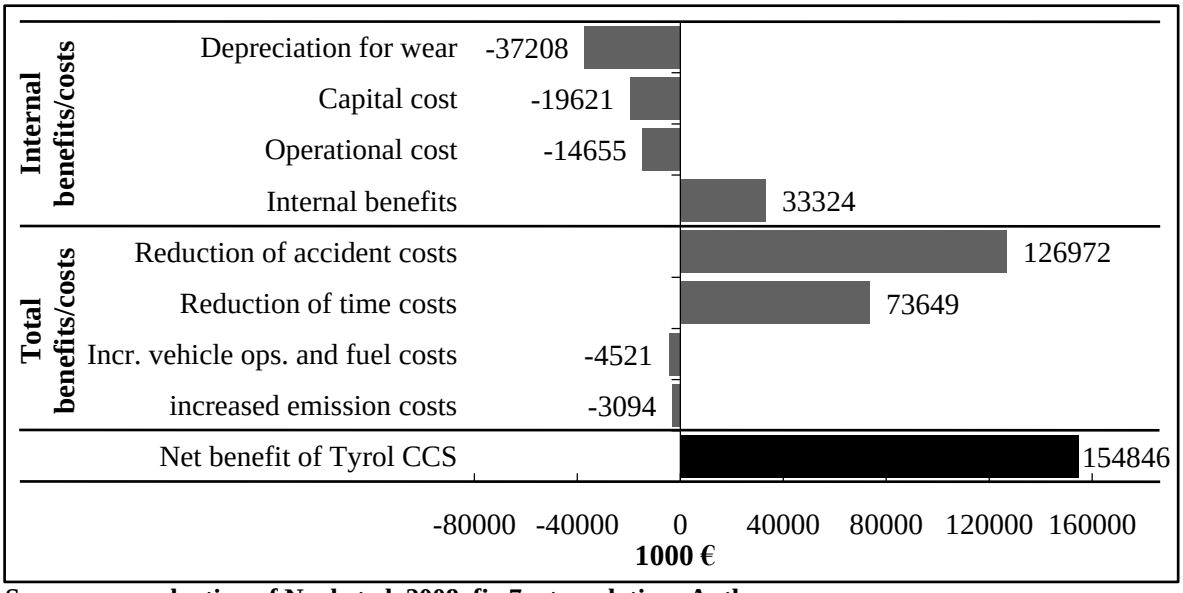
outweigh possible internal benefits. This underlines the initial assumption derived from the economic character of the good.

Figure 17: Tyrol CCS ex-post static results - internal and total benefits and costs in the first year of operation



Source: reproduction of Nagl et al. 2008, fig.6 – translation: Author

Figure 18: Tyrol CCS ex-ante dynamic results - present values of the internal and total benefits and costs from the period between 2005 and 2030



Source: reproduction of Nagl et al. 2008, fig.7 – translation: Author

Sensitivity testing found that the most relevant impact may be noticed when modulating the accident input figures. The result however is found to be robust since even under unfavorable conditions, the BCR remains above the value of 2.

4.1.5 Contemplation of the case

Regarding the critical issues of CBA methodology (definition of cases, monetary valuation, aggregation and sensitivity testing), the conducted evaluation of the Tyrol CCS appears to be

coherent with theoretical stipulations. Also the choice of the method in the light of the questions to be answered by the evaluation seems optimal. Only the lack of any reference to the discount rate used in the dynamic calculations may be viewed as a notable imperfection in the publicly available documentation and the presentation of the net benefit over the 25 year period is surprising.

It is found that the scope of the analysis is very narrow. Within the functionalities of the traffic management system installed in Tyrol, only the CCS is evaluated. While a quite comprehensive account of functionalities and effects is described, not all are included in the evaluation. In part, this is due to the fact that some of the functionalities will not be active in the beginning. The opening of emergency lanes[88] and the CCS controlled by environmental conditions were for example excluded for this reason (Nagl et al. 2008, pp.135,137,139). Why other functions such as ramp metering or variable route guidance were not also evaluated is not explained in the documentation.

Further, the evaluation focuses exclusively on monetary effects or effects where monetization techniques are established and are accepted to a large extent. Effects that include extensive measurements, such as traffic changes on the secondary network, modal shifts, etc. are not taken into account. Equally; effects of increased traffic in future time periods, which involve complex predictive assumptions, are not in the center of attention. The increase of traffic volumes is implicitly accounted for by growth rates of external benefits. Here, a more complex approach to predicting the traffic volumes both for the reference case without and in the project case with the ITS in place may lead to more accurate results. Changes in volumes due to the CCS services could be represented, if they exist. Consequently the associated effects could be derived from the respective traffic volumes instead of being estimated directly. Although this approach may involve additional assumptions or modeling, it may be able to provide further clarity.

The authors of the evaluation are very cautious to not overestimate benefits of the CCS. The rate of increase of external effects (which are mainly of a positive nature) is set to a value that is lower than the predicted increase of traffic volumes for the road section. Further increases in benefits from fewer accidents are neglected completely as the numbers are held constant due to uncertainty about them. Here as well, deriving the accident numbers from traffic volume predictions would probably provide more clarity on the impact the assumption has on the result, than to just assume the figure to remain static.

Assumptions regarding user acceptance of the system are not incorporated in the analysis. In its review of the evaluation, the Federal Court of Audit suggests that significant shares of drivers do not follow the messages displayed and, respectively, do not adhere to variable speed limits. Thus a reduced effectiveness of the CCS would have to be assumed. The estimates on the stabilizing effect the CCS has on traffic flows to avert congestion would have to be reduced (Rechnungshof 2009, p.175). Here, a weakness of the Tyrol CCS evaluation of not taking into account psychological factors related to ITS, as for example discussed under 2.1.4, becomes clear.

[88] Unfortunately the journal article is not entirely clear whether or not this functionality was integrated in assumptions for the dynamic calculation. As otherwise there is no remark, the statement on the functionality to be excluded in the static evaluation shall be assumed valid for the dynamic calculation as well.

On the other hand, an argument in favor of fewer assumptions is the resulting ease of understanding the involved factors. Retracing and debate of the evaluation thus becomes easier. Also, in some cases even few assumptions may be adequately representing the project's effects.

Although the scope of the analysis is very narrow, the account of effects and the description demonstrated a broad range of issues that have to be respected, and that a CCS may very well produce contradicting effects that have to be balanced. Still, it becomes obvious that the authors faced challenges of clearly delimiting benefits from various functions of the traffic management system and the CCS being one part of it. An example underlining this observation is the incorporation of revenues from selling traffic data as internal benefits to the operator of the CCS. Here, it is questionable whether these revenues should be added specifically to the CCS evaluation since the opportunity to gather, process and sell the information is probably associated with the overall infrastructure of the traffic management system and not the CCS alone. If benefits from this functionality are included in the CCS evaluation, attention has to be paid that the same benefits are not double counted, e.g. in an evaluation of the dynamic route guidance or ramp metering functionalities of the Tyrolean traffic management system. Due to the lack of more detailed information, it is not possible to shed further light on the issue of which type and to what extent vendible information was incorporated in the internal benefits of the CCS.

It is noteworthy that the result of the analysis is very positive although many assumptions were chosen in a conservative manner and thus should not lead to overestimation of benefits. The Federal Court of Audit, however, finds that the figures on reduction of accidents were exaggerated. The analysts of the original evaluation pointed out the high relevance of these figures for the result as part of the sensitivity testing. As these figures were produced by independent experts, it appears that the significant error, leading to the ruinous critique of the results of the evaluation, had occurred before the actual evaluation. This assumption is supported by the fact that the Federal Court of Audit, which issued the criticism, chose to maintain the method and structure of the evaluation while only modulating the input figures (Rechnungshof 2009, p.174). Certainly this was motivated primarily by the objective to produce an easily comparable result. However it also constitutes an affirmation of the evaluation method as applied by Kummer & Nagl (2007). In any case, this issue depicts the high dependence of an evaluation on the input figures. In the light of the Austrian Federal Court of Audit's critique, the difficulty of gaining reliable measurements is exposed.

One of the advantages of an ex-post evaluation is the opportunity to measure actual changes regarding the effects. Because the Tyrol CCS evaluation was conducted very soon after the ITS was commissioned, this strength was reduced to some extent. Uncertainty about the input values leads to especially cautious assumptions by the analysts. Nonetheless, the evaluation was extensively criticized by the Austrian Federal Court of Audit. In the case of ex-post evaluations, the figures may be refuted or complemented by additional measurements taken. Regarding predictions for ex-ante analyses this is frequently more difficult. The increasing use of complex, undisclosed modeling approaches to predict input figures makes criticism and debate more difficult. The extensive critique of the evaluation of the Tyrol CCS may have become possible due to these issues: straightforwardness on the chosen assumptions and falsifiability of measured input figures.

For many evaluations, this is not possible. Assumptions may be debated, but only rarely can it be demonstrated that they are wrong. In this respect, the Tyrol CCS evaluation is certainly superior.

4.2 Hierarchical economic analysis of a multimodal urban traffic management system: The appraisal of Stadtinfoköln by Schott

4.2.1 Description of the project subjected to evaluation and outline of the evaluation

The second case study presents and analyzes the evaluation of the ITS "Stadtinfoköln" [89]. The proposed system is a bundle of various ITS technologies and user services. Its area of application is urban transit, where it addresses mainly motorists and, secondarily, riders of public transport. Stadtinfoköln aspires to integrate many different user services (see Table 11 for an overview) and create a central node for mobility services. This may appear as a one-stop shop for travelers' frequent mobility related concerns in the conurbation but may also facilitate traffic management. At the same time, user access to this single service unit is possible in various ways. The ITS includes collective interfaces and also allows access through individual interfaces. Services are aimed at both pre-trip and on-trip use.

Two of the functionalities of Stadtinfoköln are illustrated below. Figure 19 shows the traffic controller view and the collective user interface of the time comparison functionality. In contrast, Figure 20 presents an example of a vehicle based individual user interface to access parking space information or dynamic navigation. A specialty of the ITS as conceived is that it allows the user to carry requests or information from one individual interface to another (e.g. PC/internet to vehicle navigation system to portable device). That way, trip planning that was realized preliminary to the trip may be accessed in the vehicle and is even dynamically updated. Route guidance, even for pedestrians, is transferable to portable devices. Since, at the time, mobile communications was not as advanced as it is nowadays, the information on portable devices remained static, once transferred. The necessary computations for all functionalities are provided on a central server. Coordination and intervention is possible from a traffic management center (Schott 2004, p.34). The concept of the ITS further allows for certain components to be provided under profit-oriented conditions, e.g. a private company may offer certain marketable services and still exchange data with the rest of the system.

Stadtinfoköln received international recognition when it was presented at various conferences. It is further listed in an FHWA catalogue on international traffic management programs. The evaluation of the project was however barely mentioned and not the subject of significant debate.

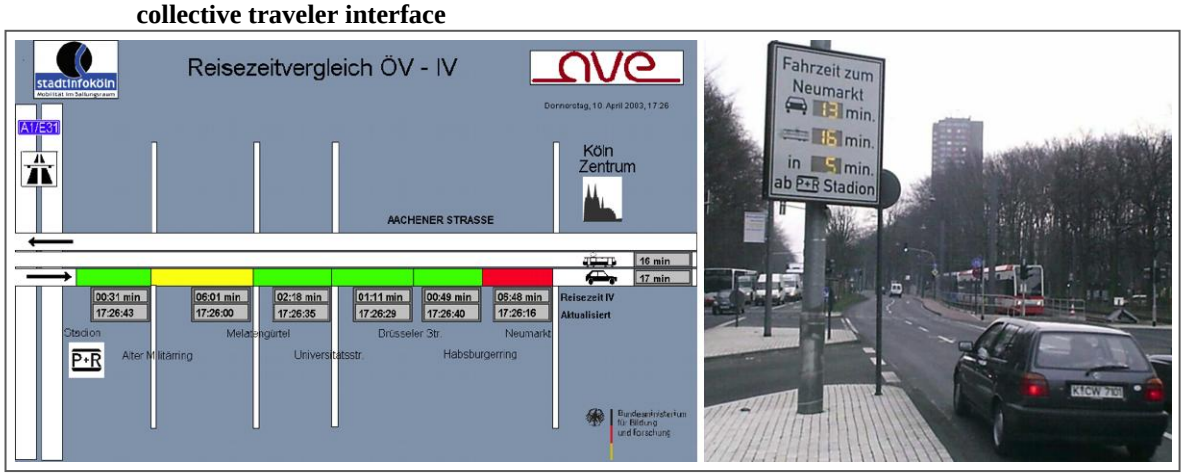
[89] Stadtinfoköln will be used throughout the text as it is a proper name. The name is a fusion of the words "city", "information" and "cologne". This designation originates from a research project, a collaboration of 16 partners under the lead of the City of Cologne government, developed between 1998 an 2002 as an answer to a 1997 research call from the BMBF. It was intended to conceive, test and evaluate an integrated ITS that would extend an already existent system. The resulting ITS with its both proposed functionalities and actually tested user services was also designated Stadtinfoköln. As the proposed technical project was the object of the evaluation described here, and not the research project, consequently Stadtinfoköln shall be understood as the designation of the proposed ITS exclusively.

Table 11: Stadtinfoköln user services

Group	*User Service*
Intermodal information service	Travel time comparison – car vs. public transit
Parking information services	Online overview map and table of car parks ParkInfo (guidance to parking opportunity) Reservations in car parks P&R-Info (map, overview and guidance to P&R facilities) Electronic parking fee payment Monitoring and prognosis of on road parking capacities
Road information services	Momentary state of road traffic in Cologne Roadway construction sites in Cologne Traffic state in other areas Road weather service
Motorist route guidance	Trip planning Dynamic navigation
Public transit information	Embedded online public transit trip planning and timetables
Other services	City map and points of interest

Source: Schott 2004, pp.39- 61

Figure 19: Stadtinfoköln travel time comparison functionality – traffic controller interface and collective traveler interface



Source: Böhnke n.d., fig.2 and fig. 3

Figure 20: Stadtinfoköln car park information and integrated route guidance functionalities – individual user interfaces in vehicle and portable device

Source: Pijls & Michaelsen 2002, fig.2, fig. 3, fig. 6

As indicated in footnote 89, the Stadtinfoköln ITS was developed during a research project. It was initiated in response to a research call and funding by the German Federal Ministry of Education and Research (BMBF). The guidelines of the ministry required evaluation of the proposed system as part of the research. The hierarchical economic analysis composed by V. Schott at the University of Cologne Institute and Seminar for Transport Economics, a partner in the research project, is a part of the answer to the BMBF requirement. The evaluation was executed as a dissertation at the indicated institution and consequently published. Aside from additional internet resources containing mainly technical information, the published thesis is the primary source used for this case study. All information presented in the subsections 4.2.2 to 4.2.5, which are dedicated exclusively to the description of this evaluation, are based exclusively on the published version of the dissertation (Schott 2004). As this fact is stated, further citations or references to the publication after every paragraph are avoided in these subsections.

The economic evaluation of Stadtinfoköln was conducted ex-ante for the time frame from 2003 to 2010. A full scale uptake[90] of the proposed ITS in Cologne is assumed. The economic evaluation was preceded by analyses of user acceptance and traffic effects which focused on pilot projects. The field tests and experiments generated information regarding important determinants of ITS effects, as described in subsection 2.1.4 for example. Assumptions and extrapolations used in the economic evaluations are adapted based on these results. Further a simulation tool is applied. This may lead to high reliability of the incorporated figures (Schott 2004, pp.61-66) as compared to evaluations which are developed for theoretically conceived projects only.

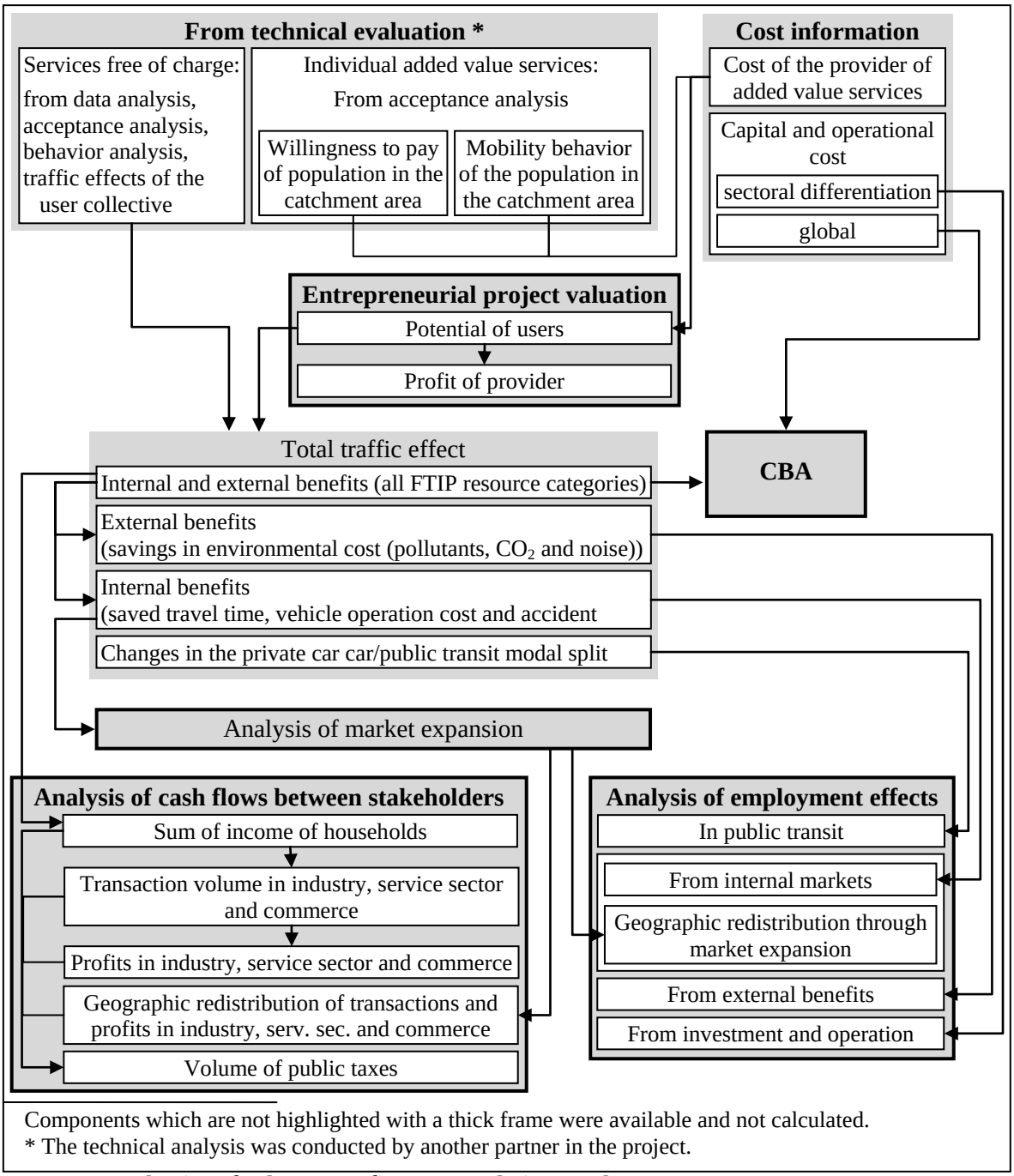
In contrast to the case of the Tyrol CCS, the questions the evaluation of Stadtinfoköln attempts to answer go beyond a statement on the desirability from the social point of view. This is coherent with exigencies regularly issued by funding agencies regarding research calls. The interest in market potentials and employment effects is often emphasized[91]. To meet the objectives set for the evaluation, a framework of various methodologies was conceived. The Stadtinfoköln evaluation consists of four components: an entrepreneurial project valuation, a CBA, an analysis of employment effects based on input-output multipliers and an analysis of cash flows which essentially measures tax revenue impacts on public budgets. The latter two evaluation components are similar to the AVA and FIA described under subsections 3.2.3 and 3.2.4 respectively. As is often the case, these concepts are adapted to the case, data and resources at hand. In practice yet, the Stadtinfoköln evaluation uses approaches that are simplified to a certain extent, compared to the descriptions' in chapter 3. At the same time, in the case of the evaluation of employment effects, additional components are added. Most likely as a result of these modifications, the analyst uses names other than AVA or FIA, or the German equivalent terms, for the respective methodological

[90] During the research project, some functions were implemented to conduct pilot tests. Some of these were limited to a single corridor only.

[91] Whether or not similar requirements were included in the original 1997 "Mobility in Conurbations" call by the BMBF could not be retraced. The website of the initiative is offline and responsibilities have been transferred to a the Federal Ministry of Economics and Technology. An archived version of the project website indicates that the main interest was focused on the evaluation of effectiveness regarding objectives for the transportation system in general (Projektträger Mobilität und Verkehr Bauen und Wohnen 2000). Hence, the extended objectives of the internal evaluation of Stadtinfoköln may also have originated from the ambition of the analyst.

steps of the evaluation. Also, the term hierarchical economic is not coined by the analyst but is assigned here as it adequately describes the evaluation framework[92].

Figure 21: Stadtinfoköln - Evaluation structure and relations between components



Components which are not highlighted with a thick frame were available and not calculated.
* The technical analysis was conducted by another partner in the project.

Source: reproduction of Schott 2004, fig.22 – translation: Author

The concept of the evaluation and the relations between each of the component methods are illustrated in Figure 21. Subsection 3.2.8 already indicated that the result of certain evaluation methods may serve as an input in other methods. In the Stadtinfoköln analysis, the analyst was able to address these interdependencies repetitively, as illustrated in the scheme.

[92] As stated in 3.3.2, the term hierarchical economic analysis does not describe one exclusive configuration of methodologies but instead constitutes an umbrella term for the concept which is applied in the case of Stadtinfoköln. It was found that the use of the term is warranted.

A detailed description of the Stadtinfoköln evaluation methodology is provided as follows. As the spatial scope and the stakeholder definitions of each component method to a certain extent depend on the objective of the respective step in the evaluation, the elaborations do not follow the same structure as adopted for the Tyrol CCS evaluation and the ADVISORS MOA under sections 4.1 and 4.3. Often the factors effects, stakeholders and method are closely interrelated. Thus, each step of the analysis, described in a dedicated subsection, is described towards these three issues. The final résumé however, regarding the result of the evaluation and the contemplation of the case, are presented separately in two subsections at the end.

4.2.2 Entrepreneurial project valuation

The entrepreneurial project valuation is limited to the ITS services of dynamic navigation and reservations in car parks[93]. These services are provided individually. Since excludability may be taken as a given, the service may be classified as a private or a club good, it is assumed that users may be charged for the service. For each of the services, a separate business model is established but it is assumed that a single company, which in addition is a monopolist, offers both services. Aside from the private ITS operator, the second involved stakeholder group is constituted by the users of the offered services. Based on the established price for the respective service, a break-even analysis is conducted from the point of view of the users. This is used to calculate the actual amount of users demanding the service, and is not directly related to a break-even analysis through the pay-off method for the private operator company.

The objective of the entrepreneurial project valuation is to measure effects affecting the private ITS operator through three indicators: the turnover, costs and profits. Effects on all other stakeholders are excluded. This also goes for investments in car parks, essential for the operation of the reservations in car parks service. It is assumed that any costs of additional elements are borne by the car park operators and the imaginary ITS operations company is not involved in any way[94]. These costs to the car park operators reappear in the social CBA and the evaluation of employment effects.

The costs to the private ITS operator have to be associated with the services offered. One must differentiate between fixed and variable components. It is assumed that the operator has to pay for the software applications and the use of hardware.

The largest part of the calculations which are part of the entrepreneurial project valuation are dedicated to establishing the price for the service and consequently determining an output quantity where the profits of the operator company are at a maximum. The calculations depart from a stated preference study, in which the willingness to pay of potential users for the use of the service is derived. Further, it is necessary to know how many persons in the region would demand the service. To this end, statistics of mobility behavior and availability of user owned access devices

[93] The commercial service of reservations in car parks is integrated with the ParkInfo function and allows electronic payment.

[94] It remains to be noted that this assumption does not appear to be very realistic as the proposed business case for the car park reservation function relies on the participation of the car park operators to whom no benefit is offered while at the same time they incur costs.

are incorporated in the analysis. Finally, the afore mentioned user break even analysis is applied to compute the amount of users at the various price levels.

Based on this information, the turnover may be calculated from which the costs are then deducted. As it is assumed that the private operator is a monopolist, the price-output relation is calculated with the goal to maximize profits only. No other constraints have to be respected. Thus the cash flows for both services the private ITS operator offers are calculated for each business period between 2003 and 2010. Aside of the profit share, neither the NPV nor the IRR are calculated.

4.2.3 Cost-benefit analysis

To analyze the social desirability of a full uptake of Stadtinfoköln, a CBA including internal and external real effects is conducted. The positive and negative benefits included are derived from intermodal shifts of traffic volumes. The ITS services are assumed to induce changes in modal choice and route choice. Only the effects of trips between locations in a defined area extending to the outer conurbation area of Cologne are taken into account, which marks the spatial and functional limits of the scope.

Two different scenarios are established of which the first one only includes direct effects of the Stadtinfoköln ITS functions. The direct effects lead to savings realized by shorter or quicker trips of car drivers and car trips not realized by individuals using public transportation instead. At the same time, the overall time spent by travelers in public transit is modified through ridership changes. Changes of traffic volumes are induced by users accessing and following the instructions of parking information services, road information services and motorist route guidance. The second scenario includes indirect effects due to changes in the attractiveness of road transportation. Thus the increase of the number of trips in private cars and the associated effects are also weighed against the reduced time spent by travelers in public transportation. The overall time spent in public transit may increase due to attracted riders or decrease as travelers choose to use private cars. Of course, the overall time spent on private car trips is thus also modified.

The effects of Stadtinfoköln, accounted for in the CBA, are listed in Table 12. In addition, the stakeholders to which the effects are attributed are presented. Regarding the inclusion of noise as an effect, the analyst found that the change in traffic volumes is too small to cause a significant increase or decrease of noise levels. The issue is consequently neglected.

To facilitate the calculation of the depreciation of investments, all capital costs are attributed to a single stakeholder. To this end, a virtual agency[95] for the operation of Stadtinfoköln is assumed in the evaluation. This virtual operator agency is supposed to initially buy all assets, respectively effectuate investments, and sell all goods at the end of the evaluation period.

[95] The virtual agency is not the private ITS operator offering the services reservations in car parks and dynamic navigation. The virtual operator agency takes over all functions of the private ITS operator but its mandate extends to activities far beyond that.

Table 12: Stadtinfoköln - Account of effects included in the CBA

Measures of effects	*Measured dimension*	*Monetary value per unit*	*Occurrence*
ITS capital cost Depreciation for wear	monetary	-	virtual operatior agency
Expansion at park ride facilities Additional public transit vehicles [a]	parking lot vehicles	3990,00 € -	v. o. agency -
ITS operational cost	monetary	-	v. o. agency, City of Cologne, car park operators
Connection fees	monetary	-	users
Travel time of private cars on arterials Travel time in public transportation Traffic volume on secondary roads	vehicle hrs. person hrs. vehicle km	5,36 € 3,83 € 1,68 €	users
Operation cost of private cars on arterials: mileage dependent fuel consumption [b]	100 v.km 10 liters	8,90 € 1,89 €	users
Accidents [c]	1000 v. km	51,29€ to 112,58€	general public
CO_2 emissions of private cars on arterials	metric tons	205,00 €	gen. pub.
CO emissions of private cars on arterials NO_x emissions of private cars on arterials	SEG [d]	24031,00 €	general public
Particle emissions of private cars on arterials [e]	metric tons	-	-

[a] As it was found that no need for investment in and operation of additional vehicles is induced by the Stadtinfoköln project, no further details are available regarding the values or stakeholders.
[b] Composite value of 0,19 €per liter of gasoline and 0,183€/l of diesel fuel assuming that 16% of vehicles run on diesel fuel.
[c] Accident costs vary on different road types. The exact associations and figures were not published.
[d] SEG is the acronym of the German term "Schadstoff-Einwohner-Gleichwert", a concept to measure the harmfulness of emitted pollutants. An SEG is calculated from the concentration of a pollutant and the number of affected persons.
[e] Effects of Stadtinfoköln traffic volume changes regarding particle emissions were measured but there is no reference that the measure was monetized or incorporated in the further steps of the evaluation.

Source: Author, Table based on the information provided in Schott 2004, pp.124-188, 202-203

The operational cost, however, is distributed amongst a variety of stakeholders, including the above mentioned virtual operator agency, the city of Cologne, car park operators and travelers sing the ITS services. Users may access Stadtinfoköln services on their privately owned devices such as PCs connected to the internet, portable or vehicle mounted devices. Here only the costs of operation of these devices, which are in essence the costs of connection time or data transfers respectively, are considered. It is assumed that users do not buy the devices solely for the purpose of accessing Stadtinfoköln services. Hence the investment cost of users for the devices is neglected. Also the cost operating collective user interfaces is only partially attributed to Stadtinfoköln project as some of the displays serve a dual purpose and were installed previous to the project.

Effects induced by changes of traffic volume, positive and negative benefits, are attributed to the users of the ITS functionalities, operators of public transit and travelers in the transit system not using the ITS functionalities. Some benefits cannot be related to a determined stakeholder or occur

to various stakeholder groups. In this case, it is considered that the effects occur to the general public which is constituted amongst others by stakeholders not directly involved with the ITS, such as travelers who only realize benefits because of other travelers using ITS functionalities or institutions such as insurance companies etc.

According to the CBA method, the effects measured in their respective dimensions have to be monetized. Valuation is based on the concept of the FTIP 2003, the values used are reported in Table 12. Isolated values that are not provided for in the FTIP are taken from specialized surveys.

Based on the effects the ITS functionalities induce in the transportation system and the expenses necessary to establish, operate and maintain the system, the costs and benefits for each year of the operation of Stadtinfoköln during the evaluation period may be computed. The invested capital is not incorporated as a single investment at the beginning. Instead, the annual depreciation is used in the calculation. The balance of the positive and negative benefits is then compared against the annual sum of the depreciation of capital and the operational costs in each year. The values of future time periods are discounted to the basis of the year 2003. The discount rate is not reported. By calculating the average value from the discounted operation periods, a standard year of operation is constructed. Aggregation is limited to the BCR of the average year of operation.

4.2.4 Analysis of employment effects

In addition to the evaluation of the social desirability realized by conducting a CBA, the analyst aims to calculate the employment effects which result from the implementation of Stadtinfoköln. Hereby four effects are assumed to affect the employment situation:

- the expenses for investments and operation of the project,
- the additional income due to net real benefits (saved resources),
- changed operational performance in public transit and
- regional shifts of employment opportunities due to changed attractiveness of Cologne compared to its neighboring cities.

The employment effects that are induced by the project expenses are analyzed by an approach similar to the AVA, as described in 3.2.3. The same concept of input-output multiplier analysis is used to assess the employment effects from investments, operation and reinvested surplus of benefits. As it was found that shifts in traffic flows induced by Stadtinfoköln do not influence public transit operations[96], the issue is not treated further. While these three sources of employment effects are based on real gains to the society (see also 2.3.2), regional shifts constitute pecuniary effects only in the sense that gains in the city and urban region of Cologne are paralleled by losses in neighboring regions. There is no improvement to the overall economy. The magnitude of these shifted employment effects is analyzed using a market expansion model and labor coefficients derived from the input-output tables. In this step of the analysis of employment effects, additional indirect effects are not taken into account.

[96] Changes in ridership do occur; the quantity of public transit services supplied however is not changed.

The first segment of the analysis of employment effects is dedicated to tracing the stimulations by the project related investments and operations. Hence both direct and indirect effects are included. The results provide insight into the employment effects in Germany in general and further, they detail which shares occur in the urban region of Cologne and the city itself. Secondary effects, meaning employment opportunities that are generated based on the expenditure of the income generated by the primary effects, are neglected in the analysis of employment effects due to lack of detailed information regarding the economic sectors where spending induces activity[97].

To facilitate the calculations of the employment effects induced by investment and operation of Stadtinfoköln, the analyst assumes that the virtual operator agency bears all project related expenses. In this case, it even takes on the complete cost of operation including the user's costs for connection fees. The virtual operator agency is consequently the only uniquely identifiable stakeholder in this component method of the evaluation.

It is necessary to attribute the investments and operational expenses to categories of goods; in this case the categories are derived from those used in the national accounts. Table 13 details the distribution. These values are assumed as changes in final demand which induce economic activities in other sectors. To the end of calculating the effects of these impulses, they are multiplied with the inverse matrix derived from the input-output tables. By using sectoral labor coefficients[98], the changes of economic activities are consequently transferred to employment opportunities measured in person-years.

Table 13: Stadtinfoköln - Investments and expenses of operation attributed to economic sectors

Expense	*Sector of the economy/category of good*	*mill. €*
Capital cost (complete depreciation) prices of 1997	Medical, precision and optical instruments	0,736
	Office machinery and computers	7,738
	Computer and related services	16,446
	Radio, television and communication equipment and apparatus	2,666
	Construction work	4,897
	Sum	32,483
Operational cost (per year) prices of 1997	Computer and related services	0,162
	Industrial services for television and radio transmitters; apparatus for line telephony and telegraphy	0,224
	Post and telecommunication services	0,184
	Real estate services	0,012
	Production and distribution services of electricity	0,133
	Sum	0,715

Source: reproduction of Schott 2004 tab. 31 – translation: Author

As one of the stated goals of the evaluation is to generate information regarding the regional distribution of effects, corresponding assumptions have to be integrated with the method. Therefore

[97] Explanations regarding the analysis of tax effects demonstrate that the secondary effects are taken into account there.

[98] $\text{Labor coefficient}_{\text{value added}} = \frac{\text{people in paid work}}{\text{value added}}$
The labor $\text{coefficient}_{\text{value added}}$ produces the same result as the labor coefficient based on the production value. The analyst chose to use the labor $\text{coefficient}_{\text{value added}}$ (Schott 2004, pp.199-200, 207).

the intensity of activity in specified economic sectors in Cologne is compared to the situation on the national level using the concept of the location quotient. Not unexpectedly, the city and urban regions show higher concentrations of businesses associated with the provision of services and less activity in the agricultural sector and manufacturing industries. The coefficients derived from the input-output tables are weighted by the location quotients.

All calculations are based on the prices of 1997 as the input-output tables of that year were the most recent available to the analyst. The labor coefficients however are adapted to the years of the investments as it was assumed that structural changes might occur.

In addition to the employment effects induced by the expenses related to the investments and operation of Stadtinfoköln, the analysis attempts to quantify employment effects which may be induced by reinvesting the project's net benefits. In contrast to the project costs, in this case it is unknown in which sectors the expenditure of the gained wealth is effectuated. To increase the detail of the analysis, the net benefits are assigned to internal and external benefits; the stakeholder in this case is the user of the ITS or the general public respectively[99]. The employment effects from net benefits attributed to external effects are calculated for the national level only; those attributed to internal effects are calculated for the national level and also reported at the level of the urban region and the city itself.

Employment effects from net benefits attributed to external effects as well as internal effects are again computed using the input-output tables. Of course, the impulses from net benefits are distributed differently according to the associations with specific sectors of the economy than the case of the projects investment and operational expenses. The assumptions regarding this distribution are not presented. The differentiation between internal and external effects is important in this case as the results are calculated for the two scenarios mentioned in 4.2.3 which exhibit a strong variation in the share of internal or external effects to ITS users respectively of the overall net-benefits.

To compute the employment effects due to shifts in attractiveness of urban centers, the trips of individuals located in the periphery of the urban region are analyzed. The basic assumption is that these persons choose their trip destinations amongst urban centers of equal supply quality due to the costs of the trip. As Stadtinfoköln lowers the cost of access to the city center of Cologne[100], according to the assumptions, some individuals situated near the boundary of the catchment area will now decide to go to Cologne instead of another city. The catchment area of Cologne consequently grows; more people will spend their money in Cologne.

The calculation of shifted employment effects is based on this diverted purchasing power. Knowing the statistical population density and the average income per year, this figure is established. Further differentiation regarding the spending of the individuals in question is necessary. Not all of the purchasing power is actually spent for consumption. Moreover only the demand for specialty goods and services may be attracted to Cologne whilst the demand for convenience goods is assumed to

[99] Consequently internal benefits are e.g. time savings realized by drivers using dynamic navigation. External benefits are e.g. changes in environmental stress.

[100] Especially time savings to motorists due to various services of the ITS.

be realized at the nearest available location and is therefore independent of Stadtinfoköln. Finally, the calculated volume of diverted spending has to be attributed to different sectors. The analyst assumes that only commerce and the services sector are affected. Economic activity in the manufacturing sector remains unchanged. The increased demand volume for specialty goods and services in the Cologne city center is multiplied with the labor coefficients of the respective economic sectors – in this case: retail and miscellaneous services. Further transmission of effects, as calculated in the AVA is not considered here. As the demand shifts, it is assumed that the supply of goods also moves from the original location to Cologne and, equally, labor follows these developments. The magnitude of the overall economic performance does not change and as supply and demand move uniformly, there are no price changes of goods due to over- or undersupply.

4.2.5 Analysis of cash flows between stakeholders

The final step in the Stadtinfoköln hierarchical economic analysis is an analysis of cash flows, as labeled by the analyst. The main objective is to provide clarity regarding the induced changes of tax revenues. The most important stakeholders are consequently the territorial authorities: the federal state, the sum of provinces and the sum of all German municipalities. Results for the municipality of Cologne are on the one hand included in the sum of the effects on all municipalities and are additionally reported separately. As for the calculation of these changes in tax revenues it is necessary to identify the tax basis. Changes in the income of households and the revenues and profits of private enterprises have to be established previously. As it is not assumed that Stadtinfoköln induces migration between regions, tax shifts resulting from this issue are assumed not to occur. The repartition of joint taxes is assumed to follow static shares.

Four effects of Stadtinfoköln are analyzed as it is presumed that they induce significant impacts on the budgets of territorial authorities via the income tax, value added tax, trade tax, corporation tax and petroleum tax:

- Increased income due to reinvestment of social net benefits in the productive process.
- Regional shifts of commerce and service sector activities due to market expansion.
- Revenue changes of public transportation agencies due to changes in ridership.
- Changed fuel consumption due to changed vehicle miles travelled.

Household incomes, economic activity and tax revenue effects are established as a part of the input-output multiplier analysis[101]. Departing from the economic activities in various sectors, the income effects are derived using statistical data regarding the average amount of taxable income in the respective sectors. Further statistical data is incorporated via the average tax rate. Hence the income tax revenues are calculated. As a byproduct, the households' disposable income is computed as well. Therefore this step in the evaluation is denominated analysis of cash flows between stakeholders, and not only the pubic budget impact analysis reflected. Since the income tax is a joint tax, its revenues are split between the territorial authorities. The cost split factors are taken from the taxation laws.

[101] These results were not mentioned in the analysis of employment effects.

To calculate the changes in revenues of companies and their profits, the same assumptions as applied for the attribution of income generation regarding the distribution in the economic sectors and the regional distribution of activities are used. The value added tax is based on the companies' revenues. The trade tax is based on the profits and it is retained by the municipality where the profit was realized. Of the remainder of the trade taxed profits, the corporation tax is deducted. Revenues from the value added tax and the corporation tax have to be allocated to the various territorial authorities as they are also joint taxes.

Shifts in economic activities between regions, as is the case with the attraction of demand, business volume and employment by the city of Cologne at the expense of comparable neighboring centers, are neutral regarding the value added tax and the corporation tax. Based on additional profits realized in the city of Cologne, owing to the attracted economic activity, the municipality's budget gains the according trade taxes. From a point of view including all municipalities, the volume of the trade tax is naturally not influenced by shifted economic activity.

The tax effects from changes in public transit ridership are derived from the impacts these changes have on the balances of the operators. Variations in their revenues and profits due to gains or losses of ridership induced by Stadtinfoköln are transformed to value added tax, trade tax and corporation tax volumes.

Concluding the analysis of taxes, modifications in the petrol tax revenues are derived from changes in of the traveled vehicle miles. To achieve a higher level of detail, the changes in vehicle miles are disaggregated for miles traveled on arterials, miles traveled in the local road network and miles traveled in search of a parking place. Each of these categories is associated with a determined level of fuel consumption. Based on the consumption and the tax rate per fuel unit, the tax volume is calculated.

An overview of tax effects is generated by summing up the isolated results regarding their occurrence at the federal level, the provinces or municipalities in general. Again, while the Cologne municipality is part of this last category, a separate calculation of Cologne-specific effects is presented which is adapted for the redistributions of the trade tax.

4.2.6 Description of results

In the following paragraphs the results of the evaluation of Stadtinfoköln are presented, and if possible, are put into context of the method or assumptions determining the result. Prior to further details, it shall be noted that the two scenarios used in the social CBA, the AVA and the analysis of tax effects produce significantly different results. The results of the first scenario, excluding indirect adaptive effects in traffic, are in all cases far more desirable than those of the second scenario. This latter scenario titled "overall effects" also includes reactions of transportation system users to the changed state of the transportation system and not only those directly related to the ITS services. It is this scenario where the evaluation generates more controversial results, which hence will be the focus of attention here.

The first step of the hierarchical economic analysis, the entrepreneurial project valuation, does not differentiate for scenarios. Regarding the private provision of the ITS service reservations in car

parks, it is found that the profit expectation is comparatively low due to the low willingness to pay of potential customers (Schott 2004, p.103). The business volume is also limited by the mobility behavior and number of potential users in the region. As it is assumed that the market saturation of access devices is already high, dynamic developments are not to be expected in the following years either. This leads to a modest profit between approximately 800 Euros per month in 2003 and 1000 Euros per month in 2010 [102] (ibid., p.118).

As for the service dynamic navigation, a positive result is not achievable in the first year, even in the light of the monopolist situation of the private ITS operator. This is the outcome of high fixed costs and a very small basis of potential customers at the beginning due to the lack of access devices owned by motorists. The loss is even greater than the profit of the reservations in car parks service. Consequently the overall result for the private ITS operator is negative (ibid.). This means that, under the given conditions, it would not be recommendable to privately operate the dynamic navigation service under the conditions present in the first year.

In contrast to the case of the reservations in car parks service, the development of the ownership of access devices allowing the use of the dynamic navigation service is assumed to be vigorous. As a result, the assumed number of users of the dynamic navigation service increases significantly[103] during the duration of Stadtinfoköln. Because of the inexistence of variable costs associated with the provision of this service, the business produces a positive result as of the second year of operation under the given assumptions. The availability of access devices to users (and thus the number of customers) is assumed to constantly increase leading to an impressively positive result. Calculated profits[104] are more than twice as high as the operational costs and depreciation annuity. This also affects the overall performance of the private ITS operator; in 2010, revenues of about 79 000 Euros per month are set against costs of approximately 26 000 Euros per month leading to a profit of nearly 53 000 Euros per month (ibid., p.119)

The results of the CBA are not conveyed in the practice of calculating a NPV, as it is frequently recommended in theory. Instead, the analyst presents a mean value for each the discounted benefits and the costs during the period of operation. These numbers reflect the performance of the project in an average year. Based on these figures, the BCR is also calculated for the average year. The scenario accounting the direct effects generates a BCR of 2,3. In the total effects scenario, the indirect effects were found to derogate the benefits of the project, leading to a BCR of 1,8 (ibid., p.189). In both scenarios, the BCR is clearly greater than 1 attesting the social desirability of the

[102] The small increase is due to a rather unspectacular development of additional availability of access devices to persons in the catchment area.

[103] It is assumed that the number of users with access devices (vehicle based navigation devices) quadruples between 2003 and 2010 (Schott 2004, p.108). It was not possible to calculate the market saturation implied by the assumptions of the Stadtinfoköln evaluation due to the lack of values provided. However, measured against the assumed number of persons with access to the internet in 2010 (1 217 626), the number of persons assumed to own vehicle mounted navigation devices in 2010 is 279 984. The assumptions regarding the development of in-car navigation devices thus cannot be proven to be unrealistic at first glance. If the evaluation were to provide results beyond 2010, a market saturation effect should be considered leading to a reduced increase and ultimate stagnation of user numbers and hence also the revenue potential for the private ITS operator.

[104] Authors note: Profits, not revenue – monthly revenues in the last year are about three times the monthly costs in the same period.

project. The consequent conclusion must be that the project should be launched. The analyst further mentions that the result of the Stadtinfoköln CBA is not directly comparable with evaluations of other ITS. While the former includes the resource consumption of the research phase to establish the functionalities, this is not done in many other cases (ibid., p.189).

A separate comparison of the realizable private and social balance is not presented as part of the study. The determination of whether certain services have to be provided by a public agency or a private organization is derived from the economic characteristics of the goods. However, the results from the evaluation may serve to reinforce this assumption. The question to be asked is to what extent profits from privately marketed services could cover the costs of the overall system. A potential annual private profit of about 53 000 Euros from sold private goods is opposed to an average need of 2,16 million Euros for depreciation of investments and operational expenditures for the system. Even without further information on the evaluation, it may be assumed that the project produces a large share of external benefits, as the total result is positive. It may be concluded that public intervention (or involvement) leading to an implementation of Stadtinfoköln is both imperative and justifiable.

Resulting from the evaluation of employment effects, it is found that the investment and operation related expenditures of Stadtinfoköln induce nearly 400 person-years of employment opportunities from 2003 until 2010 in the whole of Germany (ibid., p.211). This number is owed to about 33 million Euros of spending (see Table 13). A sectoral disaggregation of the employment effects shows that the majority occur in the economic sectors of health, veterinary and social services as well as public administration and other services. Regional disaggregation details the share of person-years which is induced directly in Cologne, and the urban region. Due to the assumptions regarding the high concentration of enterprises of the services sector in Cologne, the model predicts that approximately two thirds of the employment effects in this sector will occur in Cologne itself. In other sectors, the results attribute less than half of the person years to the urban region of Cologne and again less to the city itself while the majority is assumed to occur in the rest of Germany (ibid., p.209). Depending on the scenario and the year of the analysis, employment effects of 7 to 10 person-years are found to result from the additional economic activity made possible by the net social benefits of Stadtinfoköln. The results of the total effects scenario are especially interesting in this case: while positive benefits would make 16 person years possible in 2010, negative benefits reduce the resources available to sustain employment opportunities in a magnitude of about 7 person-years (ibid., pp.221, 228).

Based on the calculations of internal ITS user benefits the analyst derives a shift of the catchment area of Cologne from Stadtinfoköln for certain markets. In terms of area, this increase is quantified as 24 km². In terms of purchasing power, about 41 million Euros are estimated to be diverted to Cologne each year. The result amounts to additional employment opportunities of 1000 person-years per year in Cologne which are lost in neighboring cities with a comparable supply of goods and services (ibid., pp.243, 276-277).

Analysis of the tax revenue effects, indicates that Stadtinfoköln induces an additional 195 000 Euros in 2005 and a decrease of 12 000 Euros in 2010[105], reporting the values of the total effects scenario over all territorial authorities. The 2010 values list a small gain to the federal budget and a slightly higher value for the collective of municipalities. The budgets of both the provinces and the city of Cologne face a reduction of tax revenues. In the latter case, not even the shifted tax volumes may balance the decline. The reason for this lies in the decrease of taxes received from public transit operators. For these stakeholders, revenues shrink with decreased ridership while costs remain at the same level as the service level is not altered.

4.2.7 Contemplation of the case

The evaluation of the ITS project Stadtinfoköln is marked by the application of a highly complex methodological construct. Naturally, not every detail of the evaluation process could be treated in this review of the case. Additionally, it was found that various assumptions are not presented in a manner that allows a reconstruction of all important steps in the calculation. This does not imply invalidity of any part of the evaluation or its results. Further it is perfectly understood, that every publication is bound to certain limits and hence there is not room for indefinite elaborations and tables. Nonetheless, a more transparent presentation of figures and intermediate results, than the one provided by the analyst, would allow the dispersal of doubts about details of the procedure.

There are two instances where this critique becomes obvious. One example is the aggregation of the CBA's result from a dynamic series of social monetized annual benefit and cost flows during a period of 8 years to an average annual figure for costs and benefits. In this case, the steps of the calculation are described in detail. However, a complete overview of the input values is missing and further, critical figures such as the discount rate are not reported at all. A similar problem occurs in relation to the calculation of employment effects induced by the social net benefits of the ITS project. Regarding the deflation of prices to the various common price levels used (e.g. 1997 in the AVA, 1998 in the CBA, etc.), it remains unclear which index was applied. While this is a minor issue, greater problems result from the lack of clarity about the actual attribution of effects and their magnitudes to certain stakeholders. In the AVA the analyst started to categorize the benefits as internal and external to ITS users. In the CBA, where these values are actually generated, the main focus lies on the virtual operator agency but in any case the internal or external quality of benefits is not pointed out. Further, the exact role of the virtual operator agency is only defined clearly for the calculation of employment effects from Stadtinfoköln expenditures. Its role in the cost calculation used in the CBA however remains somewhat imprecise to the reader of the publication. This is in part due to the complex situation of project case and the reference case[106]. Certain cost components are listed, which are shared by the ITS of the reference case and Stadtinfoköln. Later it is mentioned that certain shares have to be deducted which pertain to the

[105] Author's calculation based on Schott (2004, pp.259-272). The figures provided by the analyst of 0,706 million Euros in 2005 and 1,02 million Euros in 2010 (Schott 2004, p.274), assume that a slump in taxes received from public transit operators is avoided by an adaptation of capacities to lower ridership. These lower ridership levels occur due to a higher attractiveness of private vehicles resulting from the Stadtinfoköln services. In the previous steps of the analysis, it was consistently assumed that the output of public transport services is not adapted to the decreased ridership. Consequently it is the author's opinion that the result of the FIA also has to be reported based on this assumption.

[106] As explained in subsection 4.2.1, the reference case also includes the operation of an ITS which, to some extent, includes technical components which are also used in the Stadtinfoköln system.

reference case ITS (Schott 2004, p.188). However, based on the provided information, it is not possible to reconstruct the exact figures. Certain methodological traps such as double counting or omission of certain cost or benefit components could hence be neither verified nor relayed.

As the evaluation was conducted at a renowned academic institute and was accepted as a dissertation, it certainly features a high level of professionalism. Nonetheless, a critical attitude when reviewing the publication is elemental. Since the given case was conducted as an internal evaluation, a possible positive bias towards the project may remain in spite of academic ambition. This may be rooted in the input figures and extrapolations often generated by other partners in the project but also assumptions or modifications to the methodology constitute a potential source of bias. Without reference material it is practically impossible to relay or criticize input values and assumptions. Two issues remain to be noted:

Assumptions regarding the usage of the ITS to a large extent determine the possible internal and external benefits and costs. In relation to Stadtinfoköln, the issue of availability of access devices (such as internet PCs, vehicle mounted navigation instruments or portable devices employed by users of the transportation system) is of special importance. The developments regarding these devices have shown a high dynamic during the last years, as was also anticipated in the presently analyzed evaluation. Were a similar evaluation to be conducted today, the initial assumptions however would most likely be significantly different. Another detail in this context are the input values and assumptions of operating costs occurring to owners of the individual user interfaces. While in the Stadtinfoköln analysis users operating individual interfaces are assumed to face internal costs from this operation, the trend nowadays shows that most users have flat-rate contracts where the costs are not directly associable with a certain application. Further, the gratuitous opportunities to connect e.g. portable devices increase. This implies a significantly altered perception of internal costs by the user. Consequently the assumption of marginal cost increases with increased consumption of ICT services may have to be adapted. Additionally, even if the user's internal cost is equal to zero in case of free connection opportunities, social costs do not vanish as resources are consumed to provide the service. The social cost of ICT services therefore may not be neglected in an evaluation. The elaborations in any case demonstrate the difficulties of evaluating ITS due to the highly dynamic development of technology and associated services. A significant change is noticeable, even during the relatively short period of about 8 years since the Stadtinfoköln evaluation was conducted. This is in harsh comparison to evaluations of transportation infrastructure construction projects where it is not uncommon to incorporate time frames of 20 years or more and the risk of unpredictable technologically induced changes of the situation is comparatively low.

The result of the entrepreneurial evaluation presents the business case as a highly lucrative investment. However, the analyst in this case excludes investment and operation costs by the car park operators, which are essential for the implementation of the reservations in car parks service. A rough estimate raises doubts that it would be possible to implement the functionality as proposed if the costs now attributed to car park operators (and which are thus external to the calculation), had

to be assumed by the private ITS operator[107]. Should the private ITS operator have to bear these costs, the result would imply that the service could not be offered by a private investor as it is not profitable.

Modifications to the theoretically proposed method raise questions as to why the analyst chose these adjustments and hence be an issue of debate. In the given case, it is especially noticeable that practically all results are presented on the basis of single calculatory periods. Only for the presentation of the entrepreneurial project valuation are the dynamics of the profit development illustrated (ibid., p.119). But even here, the absence of commonly used ways of expressing the result such as the internal NPV, the IRR or even the break even period, remains uncommented by the analyst.

Equally, there is no explanation of motives regarding the final steps of the CBA, where an average year of operation is calculated based on discounted social cash flows. One possible interpretation for choosing this static figure may be the short duration of the evaluation period. Alternatively, it is possible that the variations of the cash flows were negligible and therefore the result for an average year is a very good indication for the overall situation. The fact that the investment costs were incorporated through annuities (ibid., p.186) supports this latter theory. At the same time, none of these arguments is a cause not to also report an overall NPV or SRR.

The last step in the analysis of tax revenue effects leaves room for discussion. Here, a figure of the overall tax effects per year is not reported by the analyst. An attempt to reconstruct the value for the total effects scenario shows a negative overall tax impact[108], at least in the last year of the evaluation period. Additionally, tax revenues in this scenario appear to have a negative dynamic. The only negative figure the analyst reports is the reduction of the municipality of Cologne's tax revenues. This notable, although not overwhelming reduction, would be significantly higher were it not compensated by the revenues for Cologne from shifted economic activity (ibid., pp.273, 272). In a next step, the analyst proposes that the slump in tax revenues could be transformed to an increase if the public transit operators would adapt the provision of services to the reduced ridership. Under this supposition 24 to 35 percent of the public expenses for the Stadtinfoköln ITS could be regained through an increase in tax revenues (ibid., p.274). Here, the interested reader is left again without further information regarding which public agency's or group of territorial authorities' expenses for the ITS are the basis of the calculation and what the magnitude and composition of these expenses is. The more important problem however is that this positive result regarding the tax effects is presented in the final summary at level with the results of other component methods. The reduction in public transit service provision, which would, for example, lead to reduced employment opportunities, is not part of the assumptions determining the other results. Although the actual change in numbers may be negligible, and most likely the issue was

[107] Schott (2004, p.123) finds that the collective of car park operators would face an overall investment cost of about 350 000 Euros which would have to be depreciated over a period of three years. The overall cost of operation of the necessary ITS elements, borne by the collective of car park operators, is estimated to amount to 12 000 Euros per year. This sum, the depreciation of investments not included, is practically equal to the private ITS operators profit from the reservations in car parks service.

[108] See subsection 4.2.6.

produced unintentionally, it appears that here two results based on different assumptions are presented in line. The positive aspects of the project are thus emphasized.

Another aspect that appears to be missing at first glance is a sensitivity analysis. A part of the evaluation designated as such, or a comparable procedure, is not executed for any of the component methods. However, the majority of the parts of the evaluation compute the results for two scenarios. This is a practical approach to consistently compare variations of the inputs and assumptions throughout the diverse component methods. In the light of the vast amount of possible variations resulting from the large number of inputs and assumptions to the analysis, the scenario approach is most likely the one favoring understanding of the comparison of results. Also, as there is only one project case analyzed in contrast to the reference case, a stability of an established ranking of project alternatives cannot be tested. In addition to the analysis of alternative cases through scenarios, sensitivity testing in the given case could only serve, firstly, the identification of variables with an especially significant impact on the evaluation's result. Secondly the worst possible conditions could be identified, under which the Stadtinfoköln is still profitable or socially desirable.

Although the results of the evaluation themselves are not the focus of the thesis, the distribution of internal and external effects generated by ITS users in this case is especially interesting. Assuming the full uptake of Stadtinfoköln and taking both direct and indirect effects into account, it was demonstrated that the ITS users generate significant negative external effects by increased usage of private cars. The attractiveness of the latter increases due to the availability of ITS services. Motorists realize internal benefits but produce negative externalities. In this case, the evaluation demonstrates that a system based on information for motorists including intermodal information may very well lead to shifts from public transit inducing an increase of car traffic – with all implications.

In a concluding remark it can be stated that the hierarchical economic analysis of the Stadtinfoköln project is executed formidably. The contemplations in this subsection especially demonstrate the difficulties of making appropriate assumptions to establish the effects that are the basis of the evaluation. Regarding the complexity of the approach using various methods which to a certain extent are interlinked, very few arguable issues could be identified.

4.3 Multi-objective analysis of advanced driver assistance systems: The common assessment methodology of ADVISORS

4.3.1 Description of the project subjected to evaluation and outline of the evaluation

The third case presented demonstrates an evaluation methodology that, amongst others, takes effects into account which are not of a monetary nature or monetizable. To this end, the method of MOA was selected.

The evaluation and its method consequently described were configured and applied as part of the project ADVISORS[109]. This project was conceived and developed under the Fifth European Community Framework Programme (FP5) within the competitive and sustainable growth section. It was co-funded by the EC's DG TREN. The contents of the project are best summarized on the proper website:

"Based on test site demonstrations, ADVISORS will develop a methodology to assess the impact of different types and different levels of penetration of ADAS [advanced driver assistance systems] *in terms of the safety, efficiency and environmental performance of the road transport system. Furthermore, ADVISORS will develop implementation scenarios in order to help introducing appropriate ADAS."* (ADVISORS Consortium 2003c, sec."Project description")

ADVISORS was performed by a consortium of 16 organizations and institutions from various European countries. The spectrum includes university institutes, public research centers specialized in transport or road safety, companies from the automotive industry, logistics and insurance companies.[110]

The documentation of the ADVISORS project is comprehensive and available on the internet (ADVISORS Consortium 2003c) including the final report and the more detailed descriptions of the respective work-packages. Additionally, a journal publication by members of the consortium (Macharis et al. 2004) focusing on the evaluation is available.

A first step of the ADVISORS project consisted in screening and classifying ADAS technologies. Consequently, the ITS were qualitatively examined as to their potential contribution to solving the urgent problems of motorized traffic such as safety, environmental and efficiency issues. Also expectations regarding the possible market penetration or the desirability to key actors played a role. Of the large number of ADAS, a manageable set of less than ten technologies were selected for further study. In preparation of the subsequent evaluation, each of the technologies was situated in an implementation scenario where its effectiveness was assumed to unfold. As a result 22 alternative cases are established, constitute the project alternatives to be evaluated. An overview of the ADAS project alternatives and the number of associated scenarios are provided in Table 14. For

[109] ADVISORS: "Action for advanced driver assistance and vehicle control systems implementation, standardisation, optimum use of the road network and safety".

[110] Some of the more renowned institutions participating in the project are the German Federal Highway Research Institute (BASt), VTT Communities and Infrastructure from Finnland and Transport Research Laboratory (TRL) in the United Kingdom. A complete listing is not possible here; the reader may find the complete list in the reports or the project home page (ADVISORS Consortium 2003a; ADVISORS Consortium 2003c, Sec. Consortium).

further orientation in the Figure 23 on the result of the analysis, the acronyms used internally in the ADVISORS project are listed.

Some of the ADAS are variations of a similar technology; for example the stop&go technology is an extended version of an adaptive cruise control system. While the latter is practically a conventional cruise control system with an integrated distance monitor and breaking system, the former would also allow the system to control stopping and the acceleration of the vehicle (ADVISORS Consortium 2003b, pp.62-64, 73-75). In this case, as also in several other, the level of intervention of the ITS and consequently the effects vary considerably. Hence, the two applications rooted in the same technology are viewed as different systems. Additionally, each project alternative of the technology is adapted to the variations of setting in which the specific ADAS may be applied. In the case of the adaptive cruise control, these are scenarios of implementation on motorways considering different states of traffic density. In contrast, the driver monitoring systems are tested in scenarios which vary the intensity of the systems intervention (warning only or practical intervention) and whether the ITS is integrated in private cars or registered professionally used vehicles (Macharis et al. 2004, pp.447-449).

Table 14: ADVISORS - technical systems and scenarios to be evaluated

ADAS	*Acronym*	*Number of scenarios for this ADAS*
Stop and go support	S&G	3
Adaptive cruise control (inter-urban)	ACC	2
Lateral support system	LS	4
Collision avoidance/Lane change support	LC	2
Intelligent speed adaptation	ISA	5
Driver (drowsiness) monitoring system	DMS	4
Dynamic navigation and fleet management	NAVI	1
Integration of ADAS	INTEGRATE	1

Source: Author based on Macharis et al. 2004, p.448, tab. 1

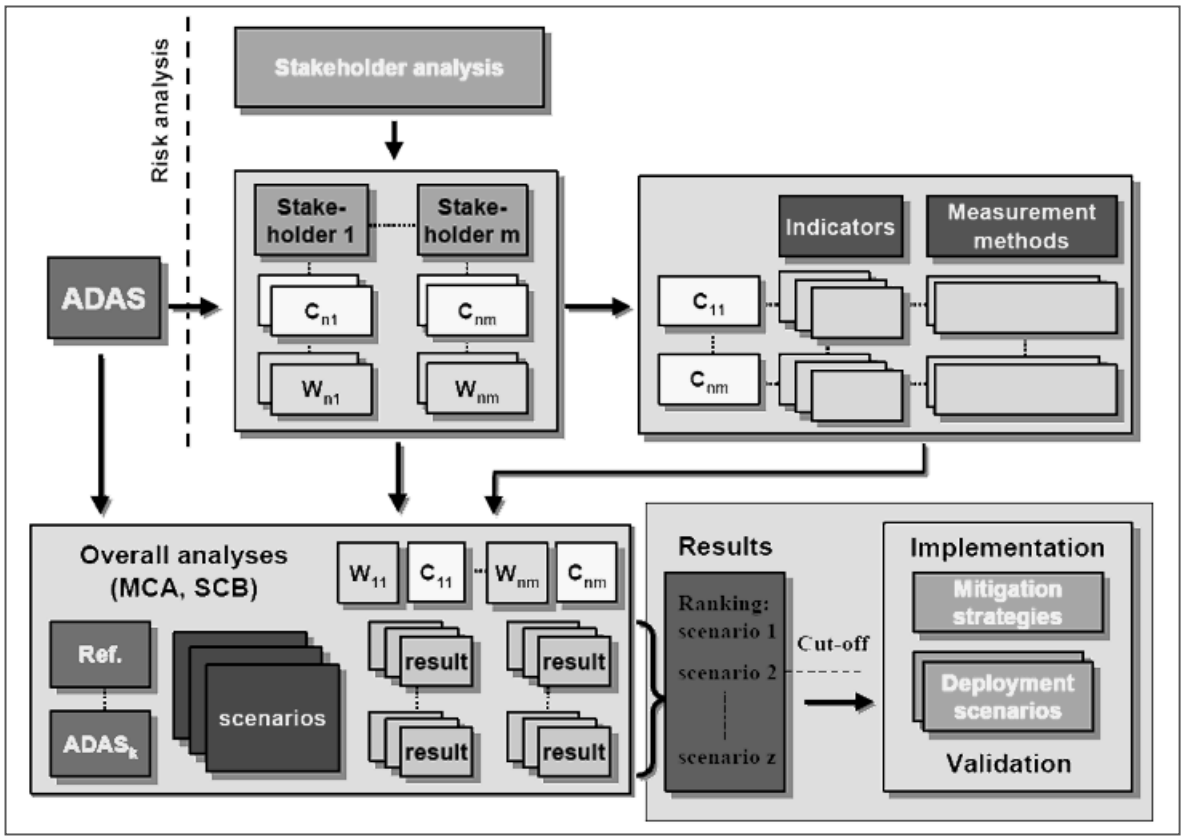
Once the project alternatives were established, the risk of failure in implementation of the various technical applications due to issues related to technology, user behavior, legal or organizational concerns was assessed. Results of this analysis were developed before the actual evaluation through MOA. However, they were only incorporated in a later part of the ADVISORS project, posterior to the actual evaluation, dealing with the implementation of ADAS. In part the MOA can also draw on the information generated in the risk analyses, to measure the performance score of the project alternatives regarding the criteria of technical risk or socio/political acceptance[111].

In the ADVISORS project, the steps of determining the criteria, weights of the criteria and scores of the project alternatives in the respective criteria are also perceived as preliminary to the actual MOA evaluation process (see Figure 22 depicting the structure of the ADVISORS evaluation).

[111] Another possible action would be to not include technologies/project alternatives with a high risk rating in the MOA since they do not qualify as fit for implementation in the first place. However, such decisions will largely be related to the specific interest of the evaluation. In the given case, a more general interest apparently leads to the inclusion of high risk project in the evaluation.

However, De Brucker et al. (2002, p.14) recognize that, in a broader sense, the establishment of the input values is part of the methodology applied[112]. Further information regarding the stakeholders, criteria and the measurements is relayed in the following subsection 4.3.2. The weighting, aggregation and ranking are explained under 4.3.3.

Figure 22: ADVISORS - structure of the evaluation methodology



Source: Brook-Carter 2002, fig.1, colors and contrasts modified

Figure 22 indicates that two methods were applied to assess the overall quality of the project alternatives. The acronym SCB refers to a cost-benefit analysis which was performed as a demonstrative example within the ADVISORS project. However, as it only focuses on one technology, the adaptive cruise control, it does not produce information whether this technology is more or less desirable than the others. Also the exact project scenario evaluated in this CBA demonstration does not conform to the project alternatives previously described. The result remains isolated. As the CBA is not further integrated with the MOA, which is the focus of the present thesis, it is not taken into account in subsequent elaborations.

Another issue that has to be clarified is the use of the term MCA in the documentation of the ADVISORS project and the use of the term MOA in the text at hand. As explained under subsection 3.2.6 the terms may be understood as synonyms. To maintain terminological stringency in this thesis, MOA will be used also in context of the ADVISORS evaluation. Naturally, MCA is equally correct.

[112] See also the elaborations on the understanding of MOA in subsection 3.2.6.

4.3.2 Scope of the analysis, stakeholders and effects included

A geographic scope of the area where effects shall be measured was not clearly defined in the ADVISORS project. As will be shown, the specific methodological approach was adapted accordingly. Defining a regional scope is thus not imperatively necessary. The importance in this evaluation lies on the technical and functional limits of the project. The scope is defined as part of the scenario in which the technology is set. Hence, the various project alternatives each have different scopes. Brook-Carter (2002, p.19) defines that the scope of an ADAS function was defined whether it was available everywhere at any time or only on certain road types or during specific conditions. This information was relevant to adequately design the implementation scenarios which then constitute the project alternatives.

Identification of stakeholders in this project is especially important as the objectives towards the ADAS are to be evaluated shall be derived mainly from the interests of the stakeholders. From a general approach, the following groups of stakeholders were recognized: road users, industry, authorities, operators, and other stakeholders (ibid., p.25). For the actual MOA, this categorization was aggregated to a set of three groups (De Brucker et al. 2002, pp.80-81):

- users – referring to individual drivers, fleet owners or other individuals or organizations putting ADAS to use.
- society – including local and national public agencies, other road users such as motorists not using ADAS or non-motorized traffic.
- manufacturers – formed by stakeholders involved with the development, production and selling of ADAS.

Once the stakeholder groups were set, research in literature and expert opinions lead to the identification of the exact objectives of these stakeholders. The evaluation criteria were established on this basis (Macharis et al. 2004, p.450). The structure was already influenced by the aggregation technique used later in the process to generate an overall performance value for each of the project alternatives. For aggregation the AHP was chosen – see also 4.3.3. The criteria define which effects of the project alternatives are measured. Table 15 lists the evaluation criteria and the description provided by the analysts. It also becomes obvious that some criteria are associated with more than one stakeholder. Here care must be taken to avoid double counting of effects (De Brucker et al. 2002, p.81) since the criteria are consequently aggregated to an overall result.

A table provided by De Brucker et al. (2002, pp.130-132) indicates that the performance of the project alternatives is actually measured through a set of subcriteria which are aggregated to constitute the respective criteria mentioned in the precious paragraph. The performance scores of the project alternatives, as described by Macharis et al. (2004, p.455), were derived from the research conducted in the early stages of the ADVISORS project. The sources for the performance measurements were the pilot studies, e.g. real road studies or simulators, as well as microscopic and macroscopic modeling. In these macroscopic models, the results of the microscopic modeling are exploited. In all cases, a reference case is compared to a state where the respective ADAS are introduced (ADVISORS Consortium 2003a, pp.51-52).

Table 15: ADVISORS - listing and description of evaluation criteria

Criterion	*Description*	*Stakeholder association*	*Weight*
Full user cost	Monetary cost of the ADAS to be paid by the user (includes purchasing cost and operating costs)	Users	0,084
Driver safety	Safety effects for the user of the system	Users	0,203
Driver comfort	Changes in driving comfort from the point of view of the driver	Users	0,077
Network efficiency/ travel time reduction	More efficient performance of the road transport network and increased capacity	Society, Users	0,107
Public expenditure	Money outlay necessary to implement the ADAS, incl. investments in infrastructure and support measures	Society	0,065
Third party safety effects	Overall change in safety from a societal point of view, i.e. the safety effects for the non-user	Society	0,183
Environmental effects	Effects on the environment (noise, emissions, etc.)	Society	0,108
Socio/pol. acceptance, acceptance risk	Societal acceptability of the ADAS by the users/decision makers	Society, manufacturers	0,083
Technical feasibility	Technical/innovation risk: the risk of failure to develop the desired system	Manufacturers	0,089

Source: Author based on De Brucker et al. 2002, fig.III.3.2 and tab. III.3.1 and fig. III.3.3

4.3.3 Evaluation method chosen and description of the valuation approach

Based on the previous steps, the MOA commences with the construction of a matrix conformed by the project alternatives and the criteria. This way, each alternative may be evaluated regarding all criteria (De Brucker et al. 2002, pp.15-16). The performance of the project alternatives regarding each criterion is assigned by the technical experts of the ADVISORS project, based on research, pilot tests and simulation results, as described in 4.3.2. In a regular MOA, the performance measures may be integrated as quantitative figures assuming that they are comparable for all project alternatives e.g. regarding the scope of the analysis. Additionally, qualitative effects can also be taken into account through operationalization. The scores of the project alternatives would then be normalized to facilitate further comparison and aggregation.

In the case of the ADVISORS evaluation, instead of directly integrating the quantitative figures and then normalizing, the performance of the project alternatives regarding a single criterion is instantly established relative to the other project alternatives. This option is a functionality of the AHP. While primarily intended for the determination of weights for the criteria, the pair-wise comparison technique may also serve to determine the scores of the project alternatives for a single criterion. Hence, the ADVISORS technical experts establish the scores of the project alternatives for each criterion on the basis of the pair-wise comparison (Macharis et al. 2004, p.455). The AHP would also allow the integration of quantitative scores for the criteria.

Once the matrix of project alternatives and criteria has been completed, it already serves to provide a first comparative overview of the qualities of the single project. However, as the amount of project alternatives and criteria involved lead to quite a large matrix which may be difficult to survey, the analysts chose to further aggregate the results. Particularly the ranking of projects would be difficult as the cases are not likely to clearly dominate each other. De Brucker et al. (2002, p.18) finds that clear dominance is a very rare case in general. Thus an aggregation of the scores in the respective criteria is necessary. Of the various aggregation methods, two were selected for closer examination: the PROMETHEE and AHP techniques. Finally, the AHP was chosen and applied in the AVDISORS evaluation.

A complete explanation of the complex AHP will not be provided at this point as it would exceed the scope of this thesis. The focus will lie on the underlying concept and the important steps to be performed and the description is consciously concise which necessarily leads to simplifications[113].

One of the most influential and creative parts (Saaty & Vargas 2001, p.9) of the evaluation is the construction of the hierarchy of goals and criteria. At the same time, it is the first step in of the AHP. The criteria used in the ADVISORS evaluation, which are used to structure the contributions of project alternatives to the overall objective, were already presented in Table 15. This framework determines which effects are actually taken into account in the evaluation.

The second most important step in the AHP is the determination of weights of the criteria. In theory, it is possible that all criteria receive the same weight. In practice, the objective is to reflect the interests of the decision maker or stakeholder groups through these weights. The technique of the AHP helps to structure the problem and reveal the conscious or unconscious preferences. The complex and probably confusing amount of information is reduced to pair-wise comparisons. Each criterion is compared to every other criterion of the same hierarchy level. The question asked hereby is how much more or less strongly a determined element of the lower hierarchy, compared to a determined other criterion at the same level, contributes to the property of the higher level criterion they are associated with. For the rating of the strength of contribution, the fundamental scale proposed by Saaty (1980, p.54), was used. The relative importance of two criteria are compared on a scale of 1 to 9 where 9 signifies extreme relative importance and 1 implies the two compared (sub)criteria are of equal importance.

Based on the pair-wise comparisons a matrix is established. Since all criteria are compared to all other criteria (in the same hierarchy, constituting the same overall criterion) independently, it is likely that different values occur. This issue is treated as the consistency of the weighting process. If the inconsistency, measured by the inconsistency ratio, surpasses a certain level it is suggested that the valuation be repeated. This was not the case in the ADVISORS project.

If the values assigned by various stakeholders or individuals differ, this may be taken care of by calculating the geometric mean. This procedure was necessary in case of the case of the

[113] A more detailed description including some explications regarding the mathematical mechanics is provided by De Brucker et al. (2002, pp.26-34) as part of the ADVISORS evaluation report. For further interest, the reader is asked to refer to the original publications by Saaty or the following books; see for example Saaty (1980) or Saaty & Vargas (2001)..

ADVISORS weighting process as several persons were invited to attribute their preferences. However, preliminary to the mathematical averaging, a discussion process is initiated to resolve the variations if possible (Macharis et al. 2004, p.452).

The valuation in the case of the ADVISORS evaluation was executed by experts from the project consortium and other external experts instead of decision makers. The criteria weights resulting from this were verified in additional studies. To this end, questionnaires were sent to authorities and students were questioned to gain insights into the user valuations. The weighting resulting from these studies are, in part, not equal to the experts' valuation as used for the evaluation The main emphasis of the respective stakeholder group was however also reflected in the expert's valuations (De Brucker et al. 2002, pp.83-85). The actual weights used for the criteria are listed in Table 15. The most weight was given to the safety effects of drivers, the safety of third parties, the environmental effects and efficiency gains from travel time reduction or network efficiency increases.

In the final step, scores of the project alternatives are multiplied with the weight of the respective criterion and these values are then summed up. The sum is the overall final score which can be compared to the results of the other project alternatives.

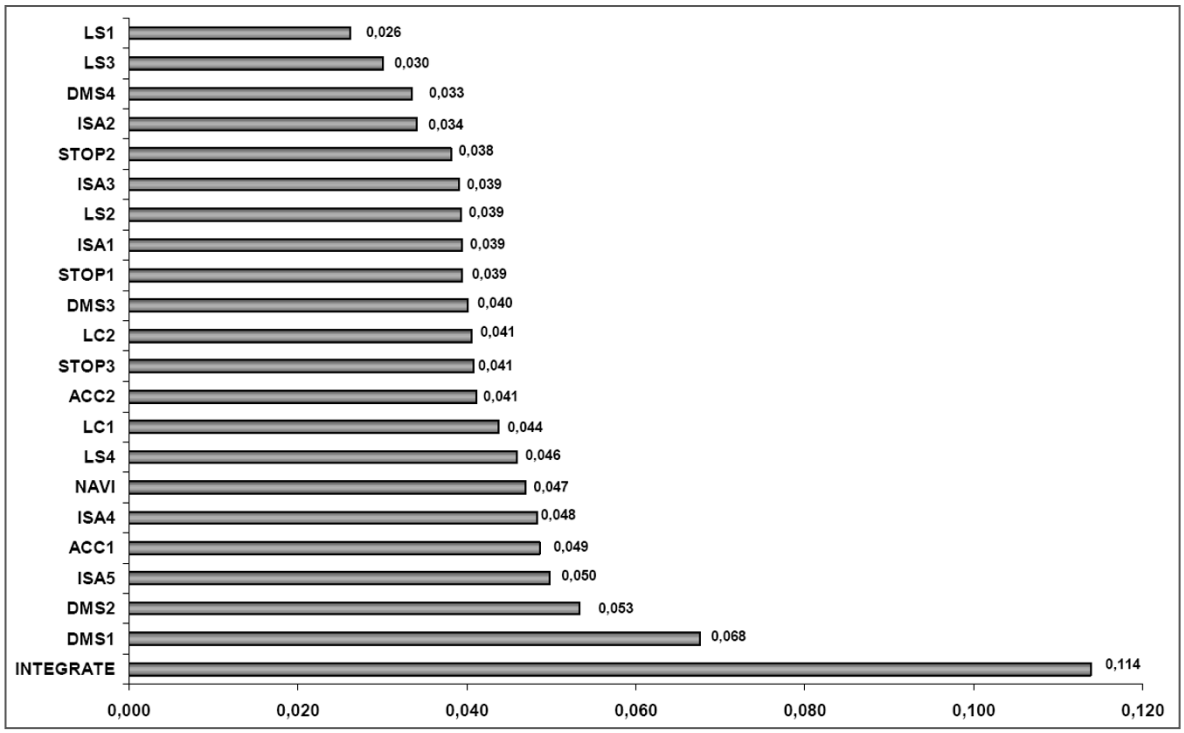
Sensitivity analysis, as described by Macharis et al. (2004, pp.459-460), includes the analysis of the single criterion's contribution to the overall rating of the project alternative. Testing was directed exclusively at the sensitivity of the result towards the weights attributed to the criteria. The impact of weight variations for each criterion is analyzed. Further scenarios of certain policy emphases such as safety or environmental interests are constructed by modifying the criteria weights accordingly. In a third step, the weights of certain criteria are maximized, or alternatively set to zero, based on the objectives of the identified stakeholder groups. This way, possible preferences of the stakeholders for one or another project alternative shall be assessed.

4.3.4 Description of results

Interpretation of the results of the aggregation process is simple. The AHP produces a complete and transitive ranking of the project alternatives. Based on the ranking, the most desirable project alternative, or a set of alternatives, may be selected. Desirability in this case is directly related to the objectives for which the criteria were constructed. Any effect, for which no criterion was designed, is neglected completely.

The actual result shows a strong prominence of the project alternative where an integrated variety of ADAS is proposed. Following this, the driver monitoring system for professional registered vehicles which issues warnings only, and after that, the variation of the same system with an intervention function appear in the list. From the fourth rank on, the differences between the scores are by far less significant. However, the next best project alternatives are an intelligent speed adaptation ITS which envisions dynamical controlling of drivers on both rural and urban roads, and finally, the adaptive cruise control system conceived in the context of high traffic density motorways.

Figure 23: ADVISORS - Final ranking result of evaluation



Source: De Brucker et al. 2002, fig.III.3.8

Sensitivity analysis of the results is thorough in the case of the ADVISORS project. The five project alternatives with the highest ranking are analyzed towards the contribution of the specific criteria to their results. The integrated ADAS case performs especially well regarding driving comfort, environmental impacts and travel time savings. The driver monitoring systems have good evaluations in the driver safety criterion. The variation of the intelligent speed adaptation at hand produced significant contributions to the safety of third parties while its rating is below average in practically all other respects. (Macharis et al. 2004, pp.456, 458)

The scenario sensitivity testing revealed that the result is quite stable to modifications of a single result and also the policy emphases do not bring about relevant changes. However, the results change significantly if only the objectives of isolated stakeholder groups are assumed to determine the weights of the criteria. Furthermore, the positions deviate so far that the ranking result for each stakeholder group is completely different to the others (ibid. 2004, p.460).

The result of the ADVISORS evaluation is used to select a subset of desirable ADAS in association with the specific scenarios. For these preferred ADAS implementations, strategies are conceived. The results of the initially performed risk analysis are integrated especially at this point. As the project is of a strategic nature, this result is oriented toward the long term implementation of the technology.

Finally, one large problem of the MOA conducted here is the introduction of additional alternatives since not only the weights but also the performance scores were determined by pair-wise comparisons.

4.3.5 Contemplation of the case

In its character of having a strategic, long term focus, the ADVISORS project is quite different from the other two cases presented. Here, the process of envisioning the project alternatives was a lot more closely related to the evaluation than, for example, in the case of stadtinfoköln where the conception of the technical project occurred independently of the subsequent evaluation. The contrast to the ex-post based CBA of the Tyrol CCS, where the technical project was implemented previous to the evaluation, is even greater. Still, a common element remains that all three evaluations attempt to identify the desirability of a technical ITS project. In the case of ADVISORS, the recommendation is further processed to a whole implementation strategy after the completion of the evaluation. In the other cases the decision on implementation would most likely be the next step.

The ADVISORS case demonstrates that when using an MOA method, there are practically no limits to the incorporation of effects. Criteria may be based on effects that are non-monetary, even originating from a qualitative basis. Thus, qualities such as driving comfort which are viewed as difficult to quantify (and monetization of which is even more problematic) can also be integrated into an evaluation without great effort.

The lack of clarity regarding the magnitudes of the performance scores of the project alternatives may be viewed critically. While the processes of establishing the hierarchy, criteria and determining the weights of the criteria is clearly described, the documentation fails to convey comprehensive information regarding the performance of the project alternatives in the evaluation criteria. Although De Brucker et al. (2002, pp.130-132) include a table of criteria, subcriteria, associated indicators, measurement methods and units as an appendix to the report, the criteria are not consistent with the ones described in the rest of the publications and further, concrete performance figures are missing. While at various points references to the results of the pilot tests and simulations are made, a single sentence states that the performances of the project alternatives are actually determined in a pair-wise comparison session. Information regarding the extent to which the experts could actually integrate the quantitative information in their pair wise comparisons is unavailable. At the same time, the circumstances of the ADVISORS project have to be taken into account: Various institutions conducted studies which produced results that are heterogeneous regarding their scope and dimensions. Hence, the structured comparison approach offered by the AHP was probably the best option under the circumstances.

The establishment of weights associated with the criteria is, in contrast to the aforementioned issue, made perfectly clear to the interested reader. The importance of the influence of the stakeholders (or analysts) invited to set the weights becomes obvious. However this is an accepted, if not intended part of the concept of MOAs and the AHP especially (Saaty & Vargas 2001, p.3). Regarding the weights determined in the ADVISORS evaluation it must be said that the result is little surprising. The participating experts (not stakeholders or decision-makers) were members of the project consortium and the Belgian Institute for Road Safety (Macharis et al. 2004, p.452). The highest weights are attributed to the criteria of driver safety and third party safety which receive nearly twice the importance of the third criterion in the list of nine criteria. It seems obvious that

the AHP was successful in its function to reproduce the conscious or unconscious priorities of the persons invited to assign the weights.

The importance of the weights of criteria to the result of the overall evaluation is further demonstrated in the sensitivity analysis. The result was found to be stable towards smaller modifications. The example of the extreme assumptions of the stakeholder based sensitivity testing however underlines the importance of the weights in the evaluation method. It further presents the issue of the subjectivity inherent to an MOA, especially if weighting is included. The fact becomes clear that the result of this method, although structured, is not reproducible if e.g. the involved parties change.

5 Summary

5.1 Findings

The basic interest of this thesis, as implied by the title, is whether or not, and if so, how projects to establish intelligent transportation systems (ITS) may be evaluated. Based on the research conducted and described in the present text, it may be concluded that, clearly, it is possible to evaluate ITS projects. Not only have a variety of evaluation methods been identified, which may be used to analyze a broad spectrum of aspects of ITS projects, but it was also confirmed that evaluations of ITS projects are performed in practice and at a highly professional level.

Intelligent transportation systems

The research on ITS made it clear that the projects summed up by this term are very heterogeneous. Even though the number of objectives, which shall be achieved by implementing ITS, is manageable, the number of possible ways to reach the goals is vast. First, this is due to the incredible variety of user services such systems may provide. Applications have been conceived for all modes of transport and within these modes. ITS may address the complete spectrum of stakeholders associated with transportation and have effects even beyond that. Second, when implementing a user service, in most cases, different technical options are available. The resulting number of possible projects is consequently very large. Although the scope of this thesis is limited to surface transportation modes only, a great number of heterogeneous ITS remain to be considered. Often the differences between the alternative concepts are significant, which is paralleled by the effects the ITS generate and the inputs necessary. This is the case both when a user service allows several technical implementations and if a system of technical components may be used to provide different user services. Generalizations on effects generated by an ITS project and their magnitudes are therefore difficult to make.

When dealing with ITS in practice, additional complexities appear: It is not uncommon that a combination of user services may be implemented as part of a single project. If advantages of complementarities or shared technical components are exploited, increased attention is required in the delineation of the scope of the project. The part of the analysis clarifying the cause-effect relationships of effects induced by the ITS also becomes increasingly important in this context. A similar issue occurs when dealing with the attribution of the occurrence of effects to one or another stakeholder. It was found that traditional assumptions on who develops and/or provides the services on the one hand, and who benefits or might suffer from the effects induced by the service on the other hand, are of little help when dealing with ITS.

For some institutions and experts, ITS incorporate the most advanced technologies by definition. As a matter of fact, the increase in ITS related activities during the last two decades was fueled and closely associated with the development of information and communication technologies (ICT). A stagnation of advancements is not conceivable, neither in ICT nor in ITS. Therefore, evaluations of ITS very likely have to constantly deal with new conditions.

Effects of intelligent transportation systems

The approach as to how the effects of a project may be identified, as presented in the corresponding subsection, includes four steps. The most important effects will be related to the objectives of the project. Normally, alongside the internal costs of the developer/operator of the project, these effects are easy to identify. Beyond that, analysts may encounter other effects when considering the project in the light of other policy goals or stakeholder objectives. Finally, systemic tracing may also be applied.

The effects of ITS may be different than those regularly measured in the evaluation of conventional transportation projects. As a consequence of the relative novelty of ITS and the constant developments in the field, experiences are scarce. Since objectives and technical implementation of projects within ITS are very heterogeneous, the effects the systems generate may also be very different. The process of identifying the relevant effects is therefore especially important. In many cases analysts may have to start from scratch. However, first steps have been taken to aid analysts. Guidelines establishing which effects may be relevant, specifically adapted to the characteristics of ITS projects, have been developed in a few countries. The guidelines, and also some scholarly authors, assume that a proper reflection of ITS effects must extend to areas which are normally neglected when evaluating projects for the construction of transportation infrastructure.

Effects on travel time and traffic safety are important in all transportation projects. Mechanisms to measure and valuate these effects are available and widely accepted. The adequate representation of environmental effects, impacts on modal choice and network effects is, in general, more difficult. Yet, an intense academic debate treats these issues and computer aided modeling instruments are successfully applied to remedy the problem. When dealing with ITS projects, these effects may be especially relevant. However, in addition to changes in travel times, ITS projects may aim to reduce delays and travel time variability. These effects are usually not accounted for in evaluations of conventional transportation projects. This also applies to effects on customer satisfaction or issues of security. Consequently, there are fewer experiences with evaluating these issues. Nonetheless, they were proposed as a performance measure for ITS projects. Attention must also be paid to the occurrence of economic activities. Due to the strong involvement of the ICT industry with ITS, the economic activities induced by these projects are likely to occur more strongly in this sector as opposed to the construction industry.

Once identified, it has to be determined whether or not the effects are tangible regarding the proposed evaluation method. Whether or not the effect is describable, measurable or monetary is of importance. The more the evaluation method specializes towards a specific evaluation objective, the more it tends to rely on measurable or monetary effects alone. In some cases, further manipulation of the input dimensions is necessary. Often it is possible to derive a quantitative value of an effect through operationalization, even though direct quantitative measurements are not possible. Further, it may be possible to attribute monetary values to non-monetary effects, thus monetizing the effect.

It is commonly agreed upon in the revised literature, that the measurement of ITS effects is a major problem. The factors leading to this situation are, first, the mentioned lack of experience, second,

the lack of well established measurement regimes for certain ITS effects and third, the characteristic of ITS effects which are often of a small magnitude and therefore difficult to isolate. When the need for predictions occurs, engineers and analysts again face the problem of lacking experience. The interrelations of ITS and the transportation system as well as the impact other determinants have on ITS effects is apparently not understood sufficiently. Factors which may strongly influence the effectiveness of ITS projects are privacy concerns or psychological reactions to ITS. There is no doubt that these issues have an influence on the acceptance of ITS as well as impacts in modal choice, traffic safety or transportation system efficiency. However, the exact mechanisms appear to be widely unknown at this point.

Regarding the investment volumes and operational costs of ITS projects, attempts at generalization have found that, in many cases, the figures are significantly smaller than, for example, in transportation infrastructure construction. In this case, clarity regarding the scope of the analysis is important as to determine whether or not activities to develop the technical prerequisites of the ITS, such as (dedicated) research activities, are included in the evaluation.

Project evaluation

It was perceived as necessary to dedicate part of the research to fundamental issues of project evaluation and the circumstances. For example, it became clear that theory on evaluation deviates from the rational decision-making approach. This propagates a determined cascade of steps reaching from the establishment of values and policies to the decision on a specific project. Three insights were gained. First, the practice of project evaluation does not always follow this concept, giving way to the engineering of evaluations to produce a desired result – which is a clear abuse of the methods. Second, decisions are necessary at different levels of advancement of projects, and hence, also in evaluation, the objects of analysis may be more or less precisely defined. The rational decision-making approach neglects this. Third, depending on the evaluation method, the definition of evaluation itself varies. While in some cases it is limited to the narrow concept of comparing and ranking project alternatives, it may in other cases go beyond the analysis of effects towards determining the values of stakeholders. Hence it is clear that there is no simple generalization of evaluation.

Stakeholders involved with project developments need evaluations to provide answers as to whether or not a project is beneficial to their interests or the interests of their constituents. On this basis, it was found that, depending on whether one is dealing with a public or a private project, evaluation interests of private and public stakeholders vary. The determined evaluation interests serve to identify the relevant methods.

Regarding the circumstances of project evaluations, it was found that except for the evaluation of potentially ecologically harmful projects, analytical evaluations are not strongly embedded in a legal framework, especially in Austria. In some cases, statements on budget impacts or the effectiveness of public projects is required. But even then, the legal texts refrain from any methodological compulsions. A different aspect is related to the interpretation of project evaluations: It was found that the relation of the analysts to the project should be kept in mind. Some evaluation experts differentiate between internal and external evaluations. Special attention

should be directed towards a possible positive bias of internally conducted evaluations. Equally this may be the case if an external analyst depends on the agent commissioning the evaluation.

Selected methods of project evaluation

As indicated above, based on the identified evaluation interests of stakeholders, a list of evaluation methods was compiled. They constitute the instruments to provide adequate decision-making support, based on structured analysis and comparison of project alternatives. The spectrum covered is very comprehensive. Seven different independent methods which were developed in economics, operational research and natural sciences were discussed in more detail. A condensed tabular comparison is provided in Table 8 under subsection 3.2.8.

- The discounting cash flow method (DCF) was presented as an advanced method of entrepreneurial project valuation. Also, a set of simpler methods was presented, as well as empirical studies published in Switzerland, which maintain that decision-makers in the private sector often prefer them. Entrepreneurial project valuation is limited to effects internal to the central stakeholder's accounting. Only effects occurring in monetary dimensions are included in this evaluation approach.
- A statement on the economic desirability regarding welfare increases of a project on a social level is produced by the cost-benefit analysis (CBA). On one hand, this objective has a distinguished importance; on the other hand a lot of work has been done on this method. Also, its result is an aggregated monetary value and therefore many stakeholders assume that interpretation is easy. This leads to CBA being probably the most frequently applied evaluation method. At the same time, some of the most basic issues still cause problems: all effects incorporated in the analysis must be expressed in monetary terms. What is a strength on the one hand, as the monetary values may be perceived as objective values attributes to certain goods by society, is also a weakness in case of intangible effects. If no way of monetization can be found, the effect must be neglected. As discussed above, some authors claim that significant ITS effects are currently intangible in CBA.
- Addressing the consequences of the economic activity associated with the project to be evaluated, the analysis of value added (AVA) employs statistical data from the national accounts and input-output-tables. Therefore the result, in terms of value added and employment effects in a region, may be viewed as highly reliable. On the other hand, the required statistical data may be out of date and it also limits the analysis to a static model of the economic system.
- The fiscal impact analysis (FIA) is an instrument to assess how the budgets of territorial authorities are influenced by a given project. The most important factors are shifts in tax flows, charges, eventual subsidies and effects that might influence the repartition of funds in intragovernmental fiscal equalization.
- Cost-effectiveness analysis (CEA) provides a comparatively simple tool to contrast the (monetary) cost of a project with the score in a determined performance measure, the effectiveness. In this, it shows characteristics of both CBA and MOA, but is a simpler version of both concepts.
- A multi-objective analysis (MOA) measures the effectiveness of the various project alternatives in a set of criteria. Therefore, the method is frequently also referred to as multi-

criteria analysis (MCA). These criteria may reflect the desirability of the project regarding different objectives. In principle, it is possible that the performance measures of the different criteria exist in different dimensions. In case of complex evaluation problems further aggregation may be necessary. An immense variety of techniques has been developed to this end. In Germany and Austria, the "Nutzwertanalyse" is a common tool suggested for transportation planning. Various authors also suggest the use of the analytic hierarchy process (AHP) in the context of ITS evaluations. The AHP is based on pair-wise comparisons to determine the values for each criterion in a hierarchy of goals.

- Environmental impact assessments (EIA) may be interpreted more as a decision making process. Its steps are clearly determined by the respective national laws. Various project evaluation methods may be included in the process to formulate the environmental impact statement, such as MOA modified to environmental risk analysis (ERA), CBA, and also others that are not discussed as part of this thesis. It also includes elements for the participation of stakeholders affected by the project. However it is complex, costly and only required for determined, potentially environmentally harmful projects.

The available literature was found to be strongly segmented, focusing on single methods or groups of methods with a similar origin or objective. In part, this is a natural consequence of the level of specialization the research on evaluation methods has reached. On the other hand, the fact that the methods originate in different academic disciplines certainly contributes to the fragmentation of the discourse. A meta-discipline, dealing with evaluation as such, is practically nonexistent. As a result, a common language and universally valid definitions are largely missing. Comparative overviews are rare. To a certain extent, this is remedied by work done in this thesis.

As part of these comparisons, it was found that that each method's strength is paralleled by specific problems. Hence, there is not one method that is superior to the others. Based only on the evaluation objective, a method may be viewed as more or less fit for a given purpose. If evaluation shall cover more aspects than a single method permits, one answer is to apply various evaluation methods. This approach is, among others, included in national evaluation guidelines in some European countries. Two examples on how to deal with complementary application of evaluations methods were presented: An approach developed for the evaluation of infrastructure projects in the German Federal Transportation Infrastructure Plan 2003, and the hierarchical economic analysis. While the gains regarding information of a proposed project are obvious, the increased effort of conducting such extensive evaluations must also be noted.

The evaluation methods were conceived with a broad spectrum of projects they may be applied to in mind. In some cases, as for example in evaluation guidelines, the concepts are adapted specifically to the problems of transportation projects. Only very few publications deal specifically with the evaluation of ITS projects. In this area, the debate (the statements of some authors were cited in the text) focuses on the advantages and disadvantages of CBA versus MOA. The argument that certain effects of ITS are intangible in CBA leads to a situation where many authors prefer MOA. Others simply insist that establishing new or more sensitive methods of measuring specific ITS effects is sufficient.

In the present analyses of the methods, it was attempted to include statements on the reasonable applicability for ITS projects. No method was found that would have to be determined unfit for evaluating ITS. As a matter of fact, applications of nearly all methods could be found in ITS evaluation practice. Only the stand-alone evaluation of environmental effects and formalized EIAs were not discovered.

Examples of practically conducted ITS project evaluations

In order to gain an insight into the practice of ITS project evaluations, three cases were analyzed. They were selected from a more extensive list of researched examples, based on the principle of dissimilarity of both the ITS project and the evaluation method. The quality of the available documentation was also taken into account. The choice does not reflect the frequency of occurrence of these methods. The three examples are:

1| The first case is an external evaluation of a corridor control system (CCS) on segments of Tyrolian freeways. It was executed by an academic institution and contracted by the developer and operator of the ITS. The analysts chose the CBA method, as the evaluation should shed light on the desirability of public involvement in the project. The evaluation sets out as an ex-post analysis of the CCS, and includes the effects: cost of the CCS, changes in traffic safety, travel time savings, vehicle operational cost and vehicle emissions. The principles of valuation of non-monetary effects are based on those proposed by the Austrian RVS guidelines on the evaluation of transportation projects. The ex-post analysis compares a standard year of freeway operation based on a three year period, before the CCS implementation and one year with the ITS in operation. The values were adjusted for general trends. The result describes that, while the project is not in any way profitable from an internal point of view, its social benefits significantly outweigh the total cost. In a second step, the evaluation is expanded to include the dynamic development of effects over a period of 25 years. The ex-ante analysis also produces an impressively positive result, with total benefits being more than three times as high as the cost of the project. In a review, the Austrian Federal Court of Audit passes severe criticism on the input figures and assumptions used in the evaluation of the Tyrol CCS. The methodology was not criticized.

2| The ex-ante hierarchical economic analysis of Stadtinfoköln, conducted as a dissertation within the project development team, constitutes the second case analyzed. Stadtinfoköln includes multiple ITS user services for trips in and to the urban center of Cologne, some of which have direct effects on modal choice.

For certain user services which have the character of private goods, an entrepreneurial project valuation is conducted. The annual profit shares potential private providers may achieve are calculated based on assumptions on the number and willingness to pay of potential customers versus the annual depreciation of capital investments and the operational costs. The result, stating that private investment would be possible under the assumed conditions, is not further aggregated and reported as NPV or IRR.

To determine the overall social economic desirability of the project, a CBA is conducted. An operating agency for the whole ITS is assumed; effects occurring to travelers and third parties are included. The valuation follows the concept proposed in the German FTIP 2003. From the total evaluation period, an average year of operation is computed. Depending on the assumptions, total benefits outweigh total costs by a factor of 1,8 to 2,3.

The third step in the hierarchical economic analysis is dedicated to determining the employment effects of the proposed ITS. Therefore, assumptions are made on how the expenses for investments and operation of the project are spent. Input-output analysis is used to trace the cascade of economic activities and determine where and how many jobs are created. This process is repeated with assumptions on the spending of the real net benefits induced by the project. Finally, shifted employment opportunities due to changes in the catchment area of Cologne due to the ITS are calculated. While the ITS project induces about 400 person years of employment opportunities during a period of 8 years, increased attractiveness may lead to 1000 jobs being relocated to Cologne from neighboring cities.

As a last step, the impacts on tax generation are analyzed. Taxation rates on income, business activities, and vehicle fuels were multiplied with the corresponding previously determined effects. Also, modified revenues due to changed public transportation ridership were included. Depending on the assumptions, tax revenues to national, regional and local territorial authorities may be decreased by the projects in future periods.

The whole concept of the hierarchical economic analysis applied to the Stadinfoköln project is highly sophisticated. However, especially in the final stages of presenting or aggregating the results of the component methods, the analyst tends to resort to indicators which are not treated extensively in the theoretical literature. While this is not an error, it was found that it complicated the process of reviewing the work done. Equally, retracing the steps was complicated, as the exact figures of few but essential assumptions could not be isolated.

3| A MOA was selected to complement the examples on the practice of ITS project evaluations. The analysis was an integral part of an EU funded research program on the potentials of advanced driver assistance systems (ADAS). A comprehensive list of implementation scenarios of ADAS constitutes the project alternatives to be evaluated. The scores, measuring the project performances, were based on experiments and research. However, the actual figures were generated by pair-wise comparisons between the project alternatives, following an option presented by the AHP technique. The criteria with which the project alternatives were evaluated were derived from stakeholder interests. Values were attributed to the criteria by experts in traffic safety and from the project consortium. Here as well, the analysts employed the AHP. The result of the MOA is a relative ranking of the project alternatives based on an aggregated dimensionless indicator. While the description of the process of determining the values of the criteria is formidable, and the sensitivity analysis is also thorough, the treatment of the performance measures of the project alternatives may be viewed critically. Only minimal information is conveyed in the publications. While the experiments and research were treated in a more detailed way, only a single sentence indicates that the scores were detached in some way from those (physical) measurements. Finally, an issue which is critical in all MOA approaches strongly shows in this evaluation: the dependence of the result on the stakeholders involved. The methodology however appears flawless and the example demonstrates one way of integrating non-monetizable effects and other effects which are difficult to measure.

Two of the reviewed CBAs are largely based on the concepts used to evaluate conventional transportation projects. Effects such as driver comfort, travel time variability or customer

satisfaction, as proposed in some relevant publications, are neglected. In the MOA, some were incorporated according to the projects evaluated.

The figures and assumptions on effects used as inputs in the evaluation are generally an issue prone to critique. Analysts often have to rely to a large extent on assumptions, indicative measurements or external expertise. Not surprisingly, the only published critique of one of the evaluations was centered on this issue. The high dependency of analysts on input data is underlined by the fact that all three of the analyzed evaluations used significant amounts of primary data attempting to justify assumptions. This also confirms that previous experiences on ITS effects, which the analysts could have drawn on, are rare and standardized values largely unavailable. Measurements of traffic effects were, in all cases, conducted as part of the evaluation, for example in actual operation or pilot tests.

Finally, attention is given to the results of the three analyzed ITS project evaluations. In all cases, the results favor the analyzed ITS and constitute a recommendation for (further) implementation. Also, indications were found that analysts are hesitant to make even partially negative performances explicit, if they occur. Another potentially problematic result of the research was that an academic follow-up debate on the three conducted evaluations is missing. Consequently the present findings cannot be compared with the opinions of experienced experts in the area.

5.2 Conclusions

The findings of the research done as part of this thesis are aggregated into three concise, but necessarily generalized statements:

- Projects to establish ITS are generally of a very complex nature. At the same time, the magnitudes of effects they generate are often small in comparison to other transportation projects.
- A number of highly developed evaluation methods exist to provide insights to decision-makers and other stakeholders on the effects and desirability of projects. Although not initially conceived for evaluating ITS projects, an application is possible.
- Many of the identified methods are applied in practice to evaluate ITS. The analysts adapted the methodology to the specific situation which accounts for certain variations from the theoretic propositions. Issuing sound methodological critique is not always possible, as in many cases, the documentation, if available at all, does not reveal all necessary aspects for a clear determinations.

However, a number of issues have also been identified, the importance of which is only revealed when going beyond the previously maintained structure of ITS project characteristics and effects, evaluation methodology and practical examples of evaluation.

The effort, or cost, of evaluation is neither treated in the theory on evaluation methods nor an issue in the documentation of conducted project evaluations. However, it is a fact in the practice of evaluation. The effort necessary may determine the level of detail that is possible in an evaluation.

This effort must also be seen in the context of the dimension of the project. In the light of a small project, the relevant stakeholders may only be willing to dedicate limited resources to the evaluation. As ITS projects have a tendency towards comparatively small magnitudes of effects, it may be the case that they receive only relatively small budgets for evaluation. If this is the case, methods which may be adequately performed on a small budget may be preferred in ITS evaluations. This however, is opposed to developments in transportation project evaluation towards increased comprehensiveness, e.g. through complementary use of evaluation methods.

The problems related to the measurement of, and uncertainties about certain ITS effects, can be dealt with in two ways. On one hand, it is possible to dedicate significant effort to develop proper measurement techniques or conduct resource intense measurements. On the other hand, in some cases it is possible to adapt the evaluation method, or choose a completely different approach. The characteristics of the project that shall be evaluated and the pool of available evaluation methods allow the analyst to establish a concept of how to evaluate the project. However, the objective of the evaluation, set by decision-makers or stakeholders, must always remain the principal concern when determining the method.

Also a note of caution shall be sounded regarding the exemption of certain effects which are difficult to measure. If an effect that is significant for a project is neglected, for example because it is intangible or the effort of operationalization or monetization is too high, the evaluation result will be biased. A common strategy is to attach additional, e.g. qualitative, statements to inform decision makers and stakeholders of the nature of the bias. However, if this practice interferes with the fundamental purpose of the evaluation to structure and compare information in the light of decision-making, it may be better to consider a different evaluation method in first place.

Opportunities for further research

In relation to the uncertainty associated with the prediction of effects of ITS projects, it was found that the treatment of project risks in evaluations may be of particular importance in this case. Preliminary investigations towards the techniques of risk measurement and valuation proved that those are highly complex matters of their own. They could not be sufficiently treated, given the restrictions on time and length of this thesis. Ways of taking account of risk in project evaluation were treated in the form of sensitivity analysis and scenario analysis. In practice, these approaches are common as they are rather simple. The significance of properly executing these steps as parts of ITS evaluations, shall be highlighted at this point. However, further research may be directed at more detailed examinations of risk analysis and ways to incorporate it in project evaluations.

Section 5.1 on findings reveals the heterogeneity within the field of evaluation. The comprehensiveness of the collection of evaluation methods originating from different disciplines is a special achievement of this thesis. One of the greatest challenges in this context was to overcome the difficulties of a not exclusively coherent terminology in the area and the variations within methods which at times made it difficult to determine the similarity or dissimilarity of concepts. There is certainly room for attempts to establish a common basis.

The comparison of the methods in this text is an attempt to establish if and how they are related. However, the comparison of theoretic concepts was by far not the only objective of this thesis. More detailed work in this area exists – however, comparisons on the broad spectrum of methods covered in this thesis were not found. Especially graphical or tabular representations, which are useful to communicate the respective evaluation methodologies and their relations at a glance, could prove to be a further challenge.

Any interpretations derived from the cases presented in the fourth chapter of the thesis can only be of a qualitative nature. It would be more satisfying to verify the findings on a larger basis of cases. However, on one hand, public documentations of ITS project evaluations are rare. On the other hand statistics are not established. Thus, neither a collection of primary data is feasible nor are adequate secondary data sources available. Developments in this direction do occur, but are isolated. An example of an evaluation database exists in the U.S. and publications were found to cite statistical material on ITS implementation in the U.S., Germany and Finland. Any development towards a more standardized and broadly based collection of data on (1) ITS implementation and (2) ITS project evaluations would be valuable in future research.

Recommendations

One conclusion presented is that the available budget for ITS project evaluations is often small. Another one stated that the effort necessary for evaluations in this field is currently high. This leads to unfavorable conditions for the comprehensive evaluation of ITS. However this should not be used as an argument to forgo evaluation. ITS may in some cases substitute for conventional transportation projects, meaning that they have to be evaluated in a broader context of transportation decision-making. Generating equally reliable evaluation results for ITS and other transportation projects are thus imperative. Especially since most evaluations of ITS indicate very high effectiveness rates of ITS projects, they should be increasingly included as project alternatives. It would be negligent to forgo this opportunity because of the effort to generate the evaluation results. If the cost of an evaluation is not only compared to the cost of the single project evaluated, but also considered in the context of enhancing the transportation system, it most likely will not be a significant argument against evaluations of small projects, even using complex methods. Regarding the measurement and prediction of effects, ITS themselves may contribute significantly to remedy the problem as data collection is facilitated.

The methodological foundations for comparing ITS projects in line with other transportation projects are available. Most problems do not constitute insuperable obstacles. Engineers and analysts may want to increasingly exploit the option of evaluating projects to establish ITS to further analyze the effects and determine the desirability of the projects.

When taking a look at the stakeholders' interests and, hence, the information they expect to gain from an evaluation, the main issues may be quickly determined. However, due to the advancing coalescence of private initiative and public intervention in the transportation sector and in the context of ITS specifically, the evaluation of aspects beyond the prime interests may be required by many stakeholders. The plentiful spectrum of evaluation methods will be increasingly drawn upon, requiring analysts to master more than a single method.

Acronyms

Acronyms of organizations and concepts which are well established in other languages than English are adopted. Here, the corresponding English translation of the name or designation which is provided by the responsible stakeholders is listed first, as such is available. The proper designation in the original language is appended in brackets.

ADAS - Advanced driver assistance systems

ADVISORS - Action for advanced Driver assistance and Vehicle control systems Implementation, Standardisation, Optimum use of the Road network and Safety

AHP - Analytic hierarchy process

ASFINAG - Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft

ATTC - Austrian Traffic Telematics Cluster

AVL - Automatic Vehicle Location

BCA - Benefit-cost analysis, equal to CBA

BCR - Benefit-cost ratio

BHG - Austrian Federal Budget Act (Bundeshaushaltsgesetz)

BMBF - German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)

BMLFUW - Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management (Bundesministium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft)

BMVIT - Austrian Federal Ministry for Transport, Innovation and Technology (Bundesministerium für Verkehr, Innovation und Technologie)

CBA - Cost-benefit analysis

DG INFSO - EC: Directorate-General Information Society and Media

DG MOVE - EC: Directorate-General for Mobility and Transport

DG TREN - EC: Directorate-General Energy and Transport

EC - Commission of the European Communities

EIA - Environmental impact assessment

ELECTRE - Elimination and choice translating reality (Élimination et choix traduisant la réalité)

ERA - Environmental risk analysis

EU - European Union

FHWA - Federal Highway Administration, US DOT

FIA - Fiscal impact analysis

FTIP - German Federal Transport Infrastructure Plan

FSV - Austrian Association for Research on Road - Rail - Transport (Österreichische Forschungsgesellschaft Straße - Schiene - Verkehr, formerly: Österreichische Forschungsgemeinschaft Straße und Verkehr)

FGSV - German Road and Transportation Research Association (Forschungsgesellschaft für Straßen- und Verkehrswesen)

GDP - Gross domestic product

GPS - Global positioning system

IG-L - Austrian Federal Immission Protection Act – Air (Immissionsschutzgesetz – Luft)

IRR - Internal rate of return

ICT - Information and communication technology

ITS - Intelligent transportation system(s)

MCA - Multi-criteria analysis

MCDA - Multi-criteria decision analysis

MCDM- Multi-criteria decision making

MOLP - Multi-objective linear programming

MOA - Multi-objective analysis

MOP - Multi objective programming

NPV - Net present value

OED - Oxford English Dictionary

ORF - Austrian Public Broadcasting System (Österreichischer Rundfunk)

PATH - California Partners for Advanced Transit and Highways

PROMETHEE - Preference ranking organisation method for enrichment of evaluations

RITA - Research and Innovative Technology Administration, US DOT

ROI - Return on investment

RVS - Code for the Planning, Construction and Maintenance of Roads (Richtlinien und Vorschriften für das Straßenwesen)

SIA - Spatial impact assessment

SMS - Short message service

SRR - Social rate of return

UK - United Kingdom

U.S. / USA - United States / United States of America

US DOT - United States Department of Transportation

VDV - Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen)

VÖV - Union of Public Transport (Verband öffentlicher Verkehr)

WKÖ - Austrian Federal Economic Chamber (Wirtschaftskammer Österreich)

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Databases used in research

ELTIS – European Local Transport Information Service	http://www.eltis.org
Fraunhofer IRB-Literaturdokumentationen	http://www.baufachinformation.de
IEEE *Xplore* Digital Library	http://ieeexplore.ieee.org
JSTOR	http://www.jstor.org
Oxford English Dictionary	http://www.oed.com
Scopus	http://www.scopus.com
ScienceDirect	http://www.sciencedirect.com
SpringerLink	http://www.springerlink.com
USDOT Intelligent Transportation Systems Joint Program Office :ITS Benefits, Costs and Lessons Learned Databases	http://www.benefitcost.its.dot.gov

Auxiliary utilities

Langenscheidt Fachwörterbuch Wirtschaft	
PONS language portal, English-German dictionary	http://en.pons.eu/english-german
LEO online dictionary English-German	http://dict.leo.org/

Annex 1:
Examples of Stakeholders in ITS Projects in Austria

Functional classification	*Description*	*Example of stakeholder*
Actors establishing policy and the regulatory framework	EU Institutions	EC, DG Mobility and Transport (MOVE)
	National territorial authorities	
	Federal:	BMVIT (Ministry for Transport)
	Regional:	Departments of transportation of the provincial governments
(potential) Operators of ITS	Road infrastructure:	
	Freeways:	ASFINAG
	Highways.	Departments of transportation of the provincial governments
	Local roads:	Municipalities
	Road transportation services:	
	Logistics:	e.g. Gebrüder Weiss Gesellschaft m.b.H.
	Personal mobility services:	e.g. Dr. Richard Linien GmbH & Co KG
		e.g. DENZEL Mobility CarSharing GmbH
		e.g. Taxi companies
	Rail infrastructure and transportation services:	
	Federal railway:	ÖBB
	Local and regional rail companies:	e.g. Steiermärkische Landesbahnen,
		e.g. Stern & Hafferl Verkehrsgesellschaft m.b.H.
	Public transit:	
		Ssee rail passenger transportation
	Municipal enterprises:	e.g. Wiener Linien GmbH & Co KG
	Private bussing companies:	e.g. Dr. Richard Linien GmbH & Co KG
	Transportation associations:	e.g. VOR -Verkehrsverbund Ost-Region G.m.b.H.
	Stand alone ITS services:	
	Navigation:	e.g. Mobilkom Austria AG
	Traffic Message Channel	ORF Radio Ö3

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Functional classification	*Description*	*Example of stakeholder*
Providers of ITS components and IT services	Electronics: Software and programming: Automotive industry: Internet providers: Mobile network providers:	e.g. Kapsch AG e.g. Fluidtime Data Services GmbH e.g. Magna Steyr Fahrzeugtechnik AG & Co KG e.g. Telekom Austria TA AG e.g. Mobilkom Austria AG
(potential) Users	Institutional: Individual:	See operators: road infrastructure, road transportation services, rail infrastructure and transportation services and public transit Travelers Vehicle owners
Unintentionally affected	Institutional: Individual:	Abutters, Territorial authorities Potentially anyone; commonly: Abutters Local residents

Source: Author

Annex 2:
Tabular Overview of Analyzed Examples of Evaluations of ITS

	Stand alone CBA	*Hierarchical economic analysis*	*MOA*
Project	Corridor control system Tirol	Stadtinfoköln	ADVISORS
ITS Category	Traffic management	Traveler information Electronic payment and pricing Driver assistance	Driver assistance
ITS user services and components	- Corridor control system - Dynamic message signs - Lane management	- Pre-trip information - On-trip information - Dynamic message signs - Route guidance/navigation systems - Parking management - Parking fee managment	- Stop and go system - Adaptive cruise control - Intelligent speed adaptation - Lateral control support - Lane change support - Driver monitoring systems - Navigation systems
Evaluation Goal	Ex-post comparison of total effects, determination of social desirability, ex-ante analysis of operation over 25 years	Mandatory evaluation of research project. Analysis of internal and social advantageousness of the proposed ITS extended by further issues of interest such as employment effects and income of public agencies.	Ranking of driver assistance systems to determine which shall receive further attention, e.g. implementation strategies, stimulation by public policy.
Author of analysis	Nagl, Kummer, (Vienna University of Economics and Business) Deweis, Schwietering (ASFINAG)	Schott (University of Cologne)	Project consortium, publications by: De Brucker, Macharis, Verbeke, Bekiaris and Brook-Carter
Year published	2008	2004	2002/2003
Regional level	Project area	Urban/Regional	undefined/European scale
Traffic mode	Road (freeway)	Road (urban, commuting), public transit	Road (general)
Evaluation procedures performed	CBA Sensitivity analysis	User acceptance analysis Entrepreneurial project valuation CBA AVA FIA Scenario analysis	Risk analysis Stakeholder analysis MOA (AHP weighted) Sensitivity analysis

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	Stand alone CBA	*Hierarchical economic analysis*	*MOA*
Effects included/ Evaluation criteria	Operator cost Accident frequency Accident severity Travel time Vehicle operation expenses Pollutants emitted Fuel consumption	Usage of added value services Willingness to pay for add. v. services Operator cost of add. v. svcs. provision Operator cost (full system) Travel time Vehicle operation expenses Traffic safety Pollutant contamination level CO2 emissions Employment opportunities created Employment opportunities shifted Tax revenues	Full user cost Driver safety Driver comfort Network efficiency/travel time reduction Public expenditure Third party safety effects Environmental effects Socio/political acceptance Technical feasibility
Monetization based on	specifically adapted values (national standard RVS 22.2 was in revision)	FTIP 2003 values, adapted	-
Evaluation result	Project is socially desirable	Certain user services are profitable private investments. Project is socially desirable. ~ 400 person years of employment opportunities induced, ~ 1000 shifted. Potentially negative tax revenue effects.	A system of combined ITS scores best. Of the particular systems, certain applications of driver monitoring systems achieve the highest scores.
Problematic issues	Input values used	Complexity of evaluation	Values reflect preferences of a homogeneous group of stakeholders

DCF: discounted cash flow method, CBA: cost benefit analysis, AVA: analysis of value added, FIA: fiscal impact analysis, CEA: cost effectiveness analysis, MOA: multi-objective analysis, EIA: environmental impact analysis.

Source: Author