The impact of ITS on CO2 emissions – the contribution of a standardised assessment framework

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ABSTRACT

Intelligent Transport Systems are accepted as an integral part of the transport system. They have high potential in reducing the carbon footprint of traffic while improving efficient and safe transport. The calculation of CO2 emissions arising from the transport sector incorporating the impact of ITS is a challenging task. A systematic assessment methodology will support developers, public authorities and investors in ITS solutions to make sound decisions based on comparable and transparent impact estimates. As the basis for such an assessment the fragmentation of traffic in underlying processes is suggested. These processes can be divided into transport demand related processes and driver behaviour and vehicle related processes. Together these processes lead to traffic flow. Transport processes are influenced by various factors. Both the processes itself and the factors influencing them can be affected by ITS. A systematic analysis of the potential effects of ITS on all these levels is the prerequisite for choosing a suitable modelling approach to quantify the effects. It also ensures the transparency of the modelling process by elucidating the required model sensitivities. The details of such an approach and its context from user needs to a standardised assessment methodology for ITS is described.

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INTRODUCTION

It is widely recognised that Intelligent Transport Systems (also called Information and Communication Technologies (ICT) in Transport, or Transport Telematics; in this article short also: systems) can play a major role in reducing CO_2 emissions from traffic. The particularly attractive trait of ITS is their promise to not only reduce emissions, but also improving mobility. This win-win situation is what makes them one of the popular measures in the thrive to align an efficient transport system with the path defined by goals of reducing carbon emissions.

However, since ITS can have quite complex effects on not only traffic, but also on transport demand, it is in many cases hard to predict what their exact impact will be. Decision makers of all sorts face situations where the knowledge of the impact of systems *before* their deployment – or even at early stages of their development – would help largely in making the right decisions. It would also be of great advantage if an assessment procedure would exist that makes results comparable. Costly assessments would be accepted not only by the people conducting them and commissioning them. Furthermore, higher level bodies like the European Commission have an interest in being able to transfer results from one country to another, enabling predictions of the impact of ITS on a large scale.

A standardised methodology to evaluate ITS for their effect on CO_2 emissions would be a major step forward in the struggle for a sustainable transport system. Such an assessment methodology was developed in the European project Amitran ("Assessment methodologies for ICT in multi-modal transport from User Behaviour to CO2 reduction"). In contrast to existing approaches, Amitran offers an improved impact methodology for assessing the effects of ITS on energy efficiency by looking at the effect chains and by offering one standardised methodology for all existing or currently conceivable ITS for all surface transport modes, freight and passenger traffic, and on all geographical scales (regional, national, European). The overall idea is illustrated in Figure 1 with the focus of this article highlighted. A description of the remaining steps can be found in [1].

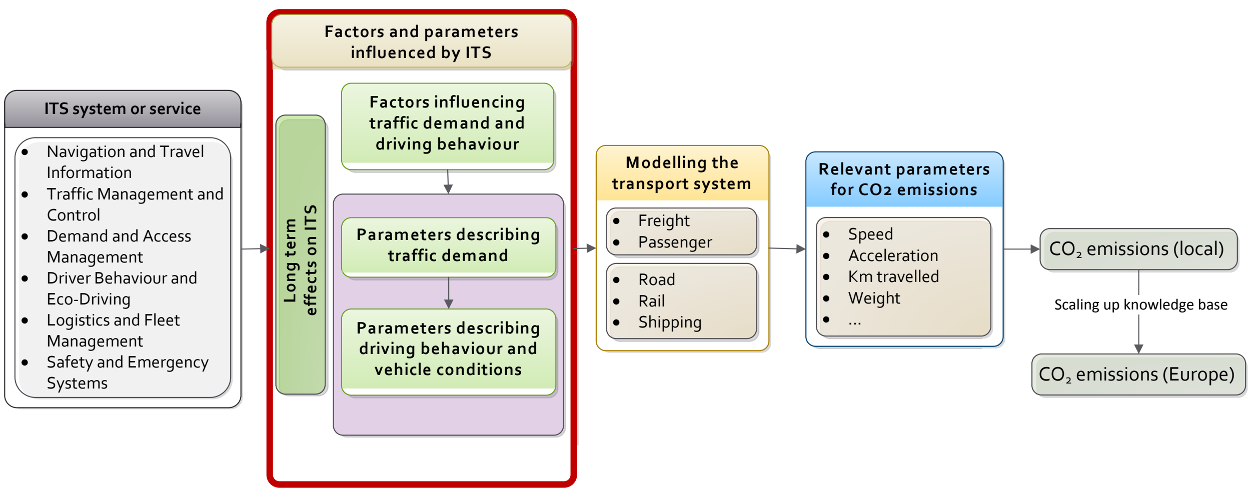

Figure 1 Methodology overview

This article scrutinises the prerequisites for a standardised methodology. It starts with the expectations of such a methodology and the resulting requirements, which have been investigated by a user needs survey and expert consultations. The major focus of this article is directed at the potential effects of ITS on traffic and CO_2 emissions and a systematic approach to analyse them. Out of a theoretic qualitative assessment of ITS a modelling framework is derived which enables the quantification of effects of specific systems. A categorisation of systems not only according to their function but also to their expected effects is provided.

WHAT IS NEEDED FOR A STANDARDISED METHODOLOGY FOR ITS ASSESSMENT?

User needs assessment

Various stakeholders are involved in the assessment of ITS. Therefore a standardised assessment methodology is confronted by diverse user needs. In order to address these user needs, a user needs assessment was conducted and requirements were derived from these needs. An initial workshop with various experts in the field served as a starting point to make sure that no relevant stakeholders are missed in the user needs assessment. A second step consisted of an extensive online survey aimed at a broad range of potential stakeholders. This questionnaire was eventually complemented by in-depth discussions with selected stakeholders to enable clarification of issues only touched upon in the questionnaire. A literature review, primarily of projects either related to ITS and their effects, or on assessment methodologies in related fields, served as a state-of-the-art analysis and identification of research needs [2].

The user needs assessment revealed three major user groups of a standardised assessment methodology: the stakeholders applying the methodology themselves, the stakeholders requiring or commissioning the use of such a methodology, and the stakeholders being affected by the methodology. Figure 2 exemplifies this assignment of stakeholders. It can be seen that many stakeholders can belong to different groups, sometimes at the same time. ITS developers, for instance, might base their development efforts on the outcome of an assessment, which they conducted themselves. Thus, they are affected by the assessment, required it (due to their interest in the results) and applied it.

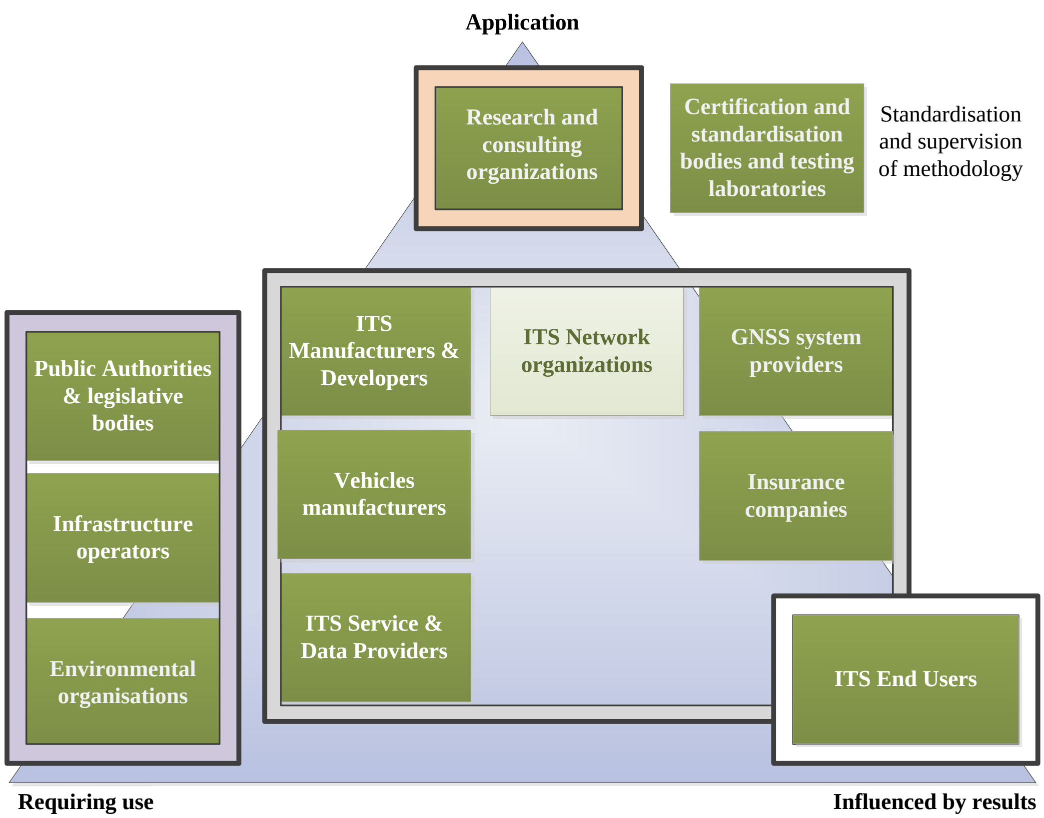

Figure 2 User groups

The comprehensive user needs assessment supported the contention that a significant need for ITS evaluations exists and high expectations are directed towards it. High level decision makers in policy and ITS development and deployment are expected to benefit most from a standardised methodology. They will use its output to compare different measures involving ITS or to compare competing systems. These decision makers will most likely not conduct the assessment themselves, but grant contracts to consultancies or research facilities for the application of the methodology. All geographical scales (from local to European) and all categories of ITS are of potential relevance to these decision makers and have to be addressed by a standardised assessment methodology. Outstanding opportunities are seen in cooperative and intermodal systems which will gain importance in the future.

The benefit of a standardised assessment methodology depends on its wide recognition to provide comparable, scalable, transparent and accurate results. CO_2 is not the only concern of most stakeholders, but one of growing importance. Traffic quality (efficiency) and safety will continue to play a major role in decisions on system development and deployment. Hence, the methodology should be seen in the context of other assessment tools. The opportunities emerging from the assessment approach should be exploited not only with respect to CO_2 effects, but also, for instance, regarding indicators reflecting the traffic quality. Interestingly, the effort to apply the methodology is not mentioned as a major concern, which indicates an open question related to the responsibility to fund the application of such a methodology.

The limitations of existing models and the combination of them will be a major challenge. Different data needs and the particularities of different model types have to be considered. It is evident that available models limit the achievable accuracy of an ex-ante assessment methodology. Hence, the methodology has to be sufficiently flexible to incorporate future improvements of models.

What has been achieved so far?

The need for a standardised assessment of ITS was recognised in the 1990s when advanced telematics systems reached a prominence that made them an inherent part of the transport infrastructure (“intelligent highways”) [3]. While the early focus was yet on project appraisal as it is conducted for conventional infrastructure investments, the potential of ITS for a sustainable transport system was recognised early on (sustainability comprising also climate effects; [4]). Thus, the assessment of emission effects induced by ITS gained prominence and became part of many ITS development and application projects.

These projects had specific implementations of ITS in focus. However, the results obtained in such projects depend on the specific setting. While they enable a before/after comparison, they can only give very rough estimates on the potential of the systems in different settings. Particularly, such an assessment does not provide benchmark comparisons to other system types.

A comprehensive appraisal of available ITS was realised in the German ITS Manual [5]. The manual describes objectives, technological aspects, effects, and challenges/opportunities of nine different system categories based on expert consultations and literature reviews. While the manual is intended as decision support for stakeholders particular from municipalities and conurbations, it does not offer a methodology for the appraisal of existing or future systems.

Several recent projects analysed specific systems or families of systems mainly based on field operational tests, partly in combination with simulations to generalise the results of the tests. Prominent examples are the EU projects ICT-Emissions and eCoMove. ICT-Emissions covers a family of systems with the focus on systems influencing drivers on roads. The methodology is based on a combination of traffic, driver behaviour and emission models that simulate the impact of infrastructure measures, driver assistance systems and eco-solutions, or a combination of measures, on energy consumption and CO_2 emissions. By taking the change in the dynamic operation of the vehicle as the focal point of the assessment, mainly influences on traffic volume, speed profile and vehicle dynamics are analysed. Effects on travel demand are seen as subordinate to driver behaviour [6].

eCoMove includes different cooperative systems for routing, driving support and traffic management with the intention to make road traffic more efficient. The focus was on the system development, but the ex-post evaluation of the systems combining field tests, driving simulation and traffic simulation was an integral part of the project [7]. The evaluation is built along the FESTA methodology [8], which is a good practice handbook for field operational tests.

Much progress has been achieved in the field of CO_2 assessment methodologies for freight transport and supply chains. The latest success can be seen in the project COFRET, which extended the existing standards for CO_2 assessments in transport [9]. However, COFRET is based on measurements, which only exist once a system is deployed, is related to supply chains (with transport being part of them) and does not explicitly explore the effects of ITS.

Though many projects for ITS assessment have been conducted to date, no existing approach has aimed to provide a generic assessment methodology for ITS. A more thorough description of relevant research activities and projects can be found in [1].

Requirements on a general and standardised assessment methodology

In order to identify gaps in the existing approaches, requirements are derived from the user needs. A standardised methodology has to consider all potential systems with their effects on different levels and transport modes. The methodology has to aim for taking into account

- all (at least) surface transport modes (road, rail, inland waterways and short sea shipping),
- all systems,
- all potential users of the methodology,
- all effects of systems, and
- all spatial levels from local to international

Because the assessment should deliver quantitative results also for systems before their deployment (ex-ante assessment), a modelling approach is required. This approach has to be systematic to cover all possible effects of all potential systems as far as they can be foreseen at the current stage. The foundation of such an approach has to be the analysis of transport processes which can be influenced by ITS. This analysis has to be mapped on models which can quantify the effects.

ANALYSIS FRAMEWORK FOR EFFECTS OF ITS ON TRANSPORT

Essential steps of an analysis framework

An analysis framework has to comprise the following essential steps:

- problem statement including a clear system and research question definition
- identification of the models and the data required to analyse potential impacts
- data processing and model application

Several of these steps can be further subdivided. This paper focuses on the identification of models and suggests a systematic approach to identify potential system effects. Understanding these effects is the key to select suitable models and use them appropriately. Models refer to transport demand models, traffic simulation models and emission models, which are commonly all needed to conduct a system assessment. It should be noted that a generic approach will never be able to provide a detailed description of model requirements and data needs. For the application, experts with modelling experience and knowledge of the workings of a specific system are required.

Assessment of effects along effect chains

ITS rarely change CO_2 emissions directly, but influence traffic which in turn leads to changes in CO_2 emissions. This effect of ITS on traffic can follow various paths including feedback loops (e.g. the interdependency of destination and mode choice) and long-term effects. Navigation systems, to give an example, will affect the route choice of travellers, leading to shifts in travel patterns. They might also influence the attractiveness of transport modes, leading to changes in mode choice.

Multimodal navigation systems might even lead to complete shifts in travel behaviour on the long run, if new options are explored and deemed convenient by many travellers. Changes of the traffic flow are not only relevant for the network load and, thus, travel times, they might even lead to adaptations of transport supply (e.g. construction of new roads) as a long term effect. Also the emissions caused by the vehicles of which the traffic flow consists, might lead to changes in regulations (e.g. speed limits).

In order to provide a comprehensive and systematic assessment of ITS along the lines described above, these effect chains have to be analysed. The methodology described here, thus, is based on the idea that traffic can be dissected into processes (termed *transport processes*). The term is used here to describe all decisions defining transport demand and its manifestation (e.g. the manifestation of decisions on trip generation, mode, travel speed). Traffic flow is what can be observed as a result of these processes.

Transport processes are influenced by ITS, by each other and by the conditions under which they take place. The processes can be described by parameters. Another central idea behind this approach is that transport processes (i.e. the parameters describing them) can be modelled. The influences on them either have to be observed, modelled, or defined by transparent assumptions.

The basic idea is illustrated in Figure 3.

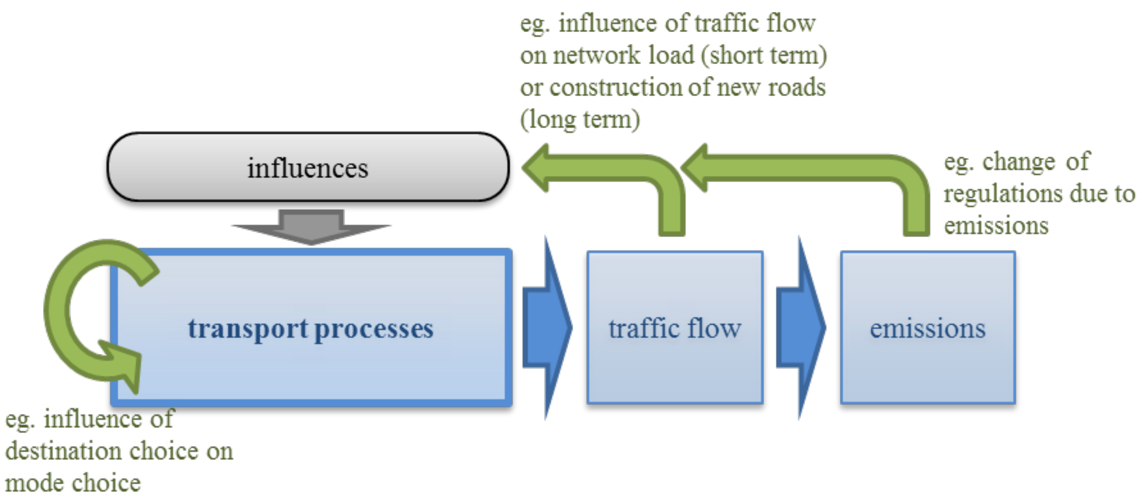

Figure 3 Effect chain from ITS to changes in CO_2 emissions

Transport processes

Two major categories of transport processes can be distinguished: processes related to traffic demand and processes describing driving behaviour (on road, railways and inland waterways). Once traffic demand and driver behaviour are known, traffic flow can be described. Energy consumption and emissions can be determined when the vehicle fleet (propulsion type etc.), the condition of the vehicles (tyre pressure, auxiliary systems etc.) and the available infrasctructure are known. . Transport processes take place during different times related to the trip itself. This can be either long before the trip (strategic planning), directly before the trip (short term planning), or during the trip. Some decisions are made in advance and revised during a trip (e.g. strategic route planning vs. on-trip route choice). Though the transport processes are derived from a road user perspective they also cover all relevant processes for the transport modes rail and inland waterways. The transport processes with relevance for transport demand are described in the following.

Trip generation

Trip generation is expressed by the number of trips made from a certain location.

Destination choice (trip distribution)

The destination choice defines the destination of a trip. An example is the choice between going to the small supermarket close by or to the large supermarket further away.

Route planning and on-trip route choice

Routes are planned before the trip and possibly adjusted during the trip.

Mode planning and on-trip route choice

Modes are planned before the trip and possibly changed during the trip.

Choice of transport means (vehicle/train/vessel)

Characteristics of transport means are the type of vehicle/train/vessel within a chosen mode and its specifics such as fuel, engine type, etc.; as specific as possible.

Load factor and occupancy

In freight transport, the load factor refers to the amount of freight relative to the capacity of the vehicle/train/vessel used. Occupancy applies to the number of passengers in a vehicle in passenger transport relative to the vehicle’s capacity.

Departure time planning and choice

Departure time choice is the choice of time when a trip starts. This can also be the scheduled time in long term planning (departure time planning).

Processes describing driving behaviour

Decisive for the traffic flow and subsequent to the determination of travel demand is the driving behaviour of vehicles. This manifests in choices on

- lane/track,
- speed,
- headway, and
- driving dynamics.

In case of railways the driver might not have the same freedom of choice than a road driver. Here speed, headways and driving dynamics are often significantly influenced or controlled by ITS or traffic controllers. The processes of choosing speed, driving dynamics, track, and headway nevertheless take place in some way. For simplicity they are subsumed here for all modes by the term “driving behaviour”.

Vehicle conditions and auxiliary systems

Vehicle conditions like tyre pressure and effects of auxiliary systems (e.g. air conditioning) are relevant for determining energy consumption and vehicle emissions.

Influences on transport processes

Traffic demand and driver behaviour are influenced by a range of factors: infrastructure properties (capacity, regulations), transport costs, access to transport means, etc. An important factor is the network load (traffic density resulting from traffic flow), which influences travel times, capacities, and thus potentially also transport costs. The factors which are relevant for travel demand and can be influenced by ITS are defined in the following paragraphs.

Network load

The network load on the available network (see below) determines travel times, but might also influence transport cost (e.g. load dependent tolls, track access auctions). The network load depends on the realised traffic demand, i.e. the traffic flow. Network load and traffic flow are, thus, closely interlinked. In models this has to be taken into account by feedback loops (iterations of demand and supply estimation).

Infrastructure

Infrastructure is defined here as the available transport network, its respective capacities (e.g. number of lanes, number of cars or train paths per time period) and infrastructure related restrictions (e.g. slope, axle load, length of trains, possible draught in loaded condition for waterways) as well as regulations like speed limits and parking or access restrictions (e.g. environmental zones). ITS can either directly influence regulations or capacities, or they can have a long-term impact on network planning.

Transport costs

All costs incurred for conducting the transport of goods or the trip of a traveller.

Availability of modes and transport means

Availability not only refers to the physical accessibility and availability of, for instance, a vehicle or public transport service, but also to the *perceived* availability (e.g. only if a user is *informed* about the availability of a car sharing vehicle, e.g. by a smartphone application, this vehicle is factually available to the user).

Connection between different transport services

Connection between different transport services refers to the alignment of departure times of different services, for example by making use of arrival time estimation (e.g. busses waiting for train arrival, lorries directed to a vessel arrival). This factor is relevant for public transport and freight only.

Location of opportunities

The location of available opportunities for desired activities like homes, work places, shops, companies, consolidation centres etc. are determining for trip generation and distribution. ITS can influence the perception of the availability and also have impacts on locations in the long term (e.g. optimisation of supply chain network leading to new consolidation centres).

Further factors and long term effects

There are other influencing factors mainly related to the properties and decision frameworks of the actors in transport (e.g. household size, income, travel budget). These, however, cannot be influenced by ITS or only marginally or on very long time scales.

Long term effects can play a relevant role for the impact of ITS. Long term effects are changes of the transport supply defined by the network, location of opportunities, transport options (e.g. public transport schedules), and logistics services. These long term effects are determined not by decisions of travellers, but by decision makers on higher level (policy, operators). These effects, hence, play a special role and are usually addressed by reference to master plans, by assumptions or scenarios. Another long term effect is induced traffic, i.e. long term changes in travel behaviour.

A complete picture of all transport processes sorted by the time of their occurrence with reference to the trip and grouped into driving behaviour/vehicle conditions, traffic demand, influencing factors, and long-term effects is shown in Figure 4. This figure takes all kinds of traffic and all (surface) modes into account. It also applies to both freight and passenger traffic.

The transport process identification and description underwent a review by experts on the respective systems and was tested for completeness by its application for the purpose of ITS assessment. The framework was used for a qualitative assessment of systems as the basis for the derivation of modelling needs as will be described further below.

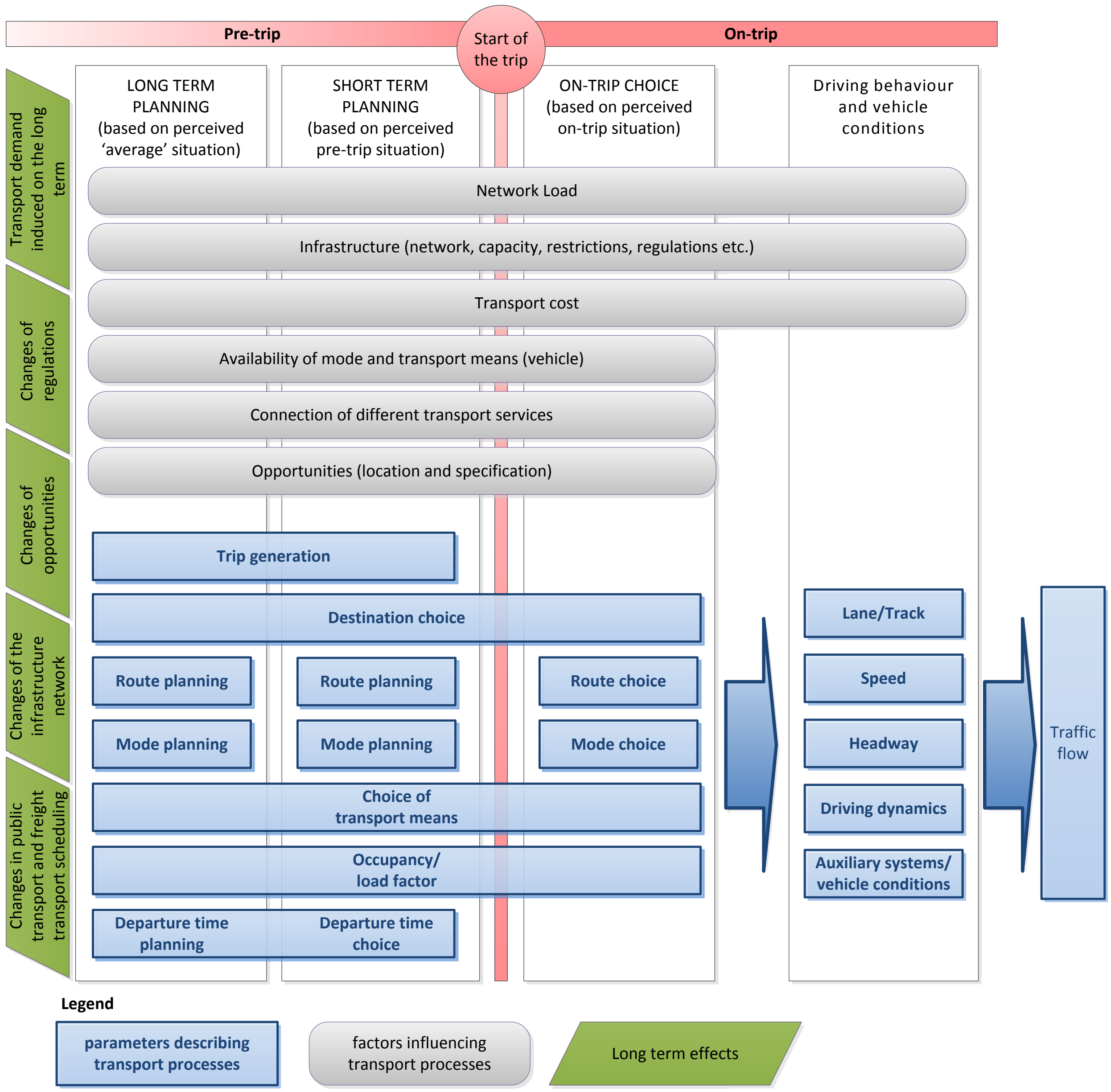

Figure 4 Transport processes, influences on them, and long-term effects

QUALITATIVE AND QUANTITATIVE IMPACT ASSESSMENT

Qualitative assessment of ITS

The approach described in the previous section facilitates the systematic analysis of ITS effects. The aim of such a qualitative analysis is the identification of processes which are potentially influenced by an ITS. This knowledge not only gives an insight into the likely relevance of the system for emission changes, but also enables the determination of model functionalities needed to quantify the impact. Another advantage is the identification of potential mutual effects of systems to each other.

The qualitative analysis was conducted in three steps. Starting point was a literature review, taking existing knowledge of system effects into account. The effects described in the literature had to be related to the transport processes described before. The second step consisted in consultation of experts in the respective fields (25 in total). The experts were provided with a questionnaire asking for the potential effects of specific systems on the described transport processes (no impact, low impact, high impact). Finally, the results of this consultation were consolidated and uncertainties clarified by discussing the reasoning behind judgments. Because for most of the more than 40 analysed systems several experts were contacted, the range of conceived effects was elucidated and could be addressed.

A major outcome of this analysis was the high dependence of ITS effects on the design of the system and the setting in which it is deployed. While the effects of some ITS can clearly be qualitatively foreseen, some systems can have even contrary effects depending on their deployment, acceptance, exact functionalities, and setting. To underpin this statement the results for two systems as examples are shown and discussed below. The systems are chosen to illustrate the range of possible challenges, but also highlight the opportunities arising from the described assessment approach. Details also for all other analysed systems are documented in [10]. The effects described in the literature are provided in condensed form for the example systems and are amended by the expert assessment and its discussion. It is *not* the purpose of this qualitative assessment to replace a quantitative assessment of these systems and judge their impact on CO_2 emissions. The assessment is focused on their impact on transport processes and traffic flow only.

Example 1: Dynamic Navigation System

Dynamic Navigation Systems are defined as mobile (vehicle mounted or portable) online navigation systems which receive up to date (dynamic) traffic information and display it on a map and/or consider this information in route suggestions. The literature states influences on

- route choice (pre-trip and on-trip), since the system can advise an alternative route that reduces the expected travel time.
- mode choice (pre-trip and on-trip), since the system can indicate that the traveller might not reach his destination in time (due to congestion) and this could cause a shift to another mode.

The experts also agreed on a high potential impact on departure time choice. However, opinions diverged with respect to the impact on trip generation, destination choice, speed and others. This is founded in the diverse possible functions of dynamic navigation systems and their use. Simple in-car systems have significantly different impact from sophisticated multimodal pre-trip systems. This underlines the limitations of a preliminary qualitative assessment and supports the need for more detailed research and modelling for specific implementations, which have to be unambiguously defined. The given qualitative assessment, however, indicates the requirements for models to be used and their input data (the modelling approach will be picked up further below).

Example 2 Road Section Control System

By using variable message signs Road Section Control Systems allow flexible speed limits, lane control, and up-to-date warning messages. According to the survey results, flexible speed limits have an impact mainly on the parameters speed, headway and driving dynamics as all drivers run at a more homogeneous speed and therefore less braking and acceleration of vehicles is necessary. Moreover, an improvement in traffic flow stability can be achieved [11, 12]. Merely advisory variable speed limits, though, were found to have no notable impact on traffic conditions [13].

Warning messages like congestion, weather hazards or road works are avoiding incidents that could cause congestion and, hence, an increase of travel times. Reduced speed limits based on adverse conditions like weather do significantly lower the risk of a crash as well, while increasing the travel time only slightly [14].

If the system allows a dynamic lane assignment or a flexible use of the emergency lane an influence on infrastructure capacity and lane choice entails. All changes in the capacity of the network might have long term effects on transport demand. Both the literature and the experts concur in their evaluation of road section control systems. Thus, the qualitative effects can be clearly foreseen. Only long term effects are harder to predict or model.

The assessment also highlights the need to distinguish sub-systems with differing functionality, namely systems displaying dynamic speed limits, dynamic lane assignments, warning messages (congestion, low visibility, road works, etc.), and systems used for dynamic shoulder use (opening of the hard shoulder during peak times).

Conclusions from the qualitative assessment

While a qualitative assessment helps to give an indication of the potential impact of systems, a detailed analysis of specific systems is required to give more reliable impact estimates. This qualitative assessment, however, helps to direct the attention of further analysis towards crucial effects. Skimming over the potential effects provided as a checklist and cross-checking them with a scrutinised specific system implementation helps the users of the assessment methodology to receive valid results from the application of the methodology. The users of the assessment's result can use such a checklist to appraise the correct application of the methodology including the suitability of models.

System categories: grouping systems with similar effects

In order to develop a generic framework for ITS assessment, the next task consists of finding a suitable categorisation for systems. This categorisation has the aim to suggest assessment steps based on the likely effects of the systems with their functionality defined. Such a structure facilitates particularly a preliminary screening of potential ITS for a specific setting and also the assessment of systems not yet deployed or described in the literature.

Many categorisations for ITS have been developed in the past, each with different perspectives [15, 16, 17, 18, 19]. With respect to the requirements mentioned above the most suitable categorisation that could be found is the one suggested by the ECOSTAND consortium. The support action ECOSTAND consolidated the results of a joint task force of EU, USA, and Japan. This task force developed the outline of a standard methodology for determining the impacts of ITS on energy efficiency and CO_2 emissions. The developed categorisation is based on a EC-METI report [20] and takes into account the one used by the Working Group on ICT for Clean and Efficient Mobility [21]. Furthermore this categorisation was discussed and agreed among the three partners [22, 23] and, hence, is broadly accepted. The suggested ECOSTAND categories are:

- Navigation and traveller information,
- Traffic management and control,
- Demand and access management,

- Driver behaviour change and eco-driving,
- Logistics and fleet management,
- Safety and Emergency.

These categories have been amended by sub-categories, defined with a particular focus on system effects. Traffic management and control systems, to provide an illustration, are divided into signal control, highway systems, railway and inland waterway systems, and different enforcement systems.

The structure is based on the aforementioned qualitative analysis of systems. Systems belonging to a sub-category can be expected to require similar modelling approaches (see below) and will have effects on similar processes. The suggested structure also helps in dealing with innovative systems that are not yet implemented by offering a framework into which also new systems can be fitted. Table 1 and Table 2 show the structure for the categories of Navigation and traveller information as well as Traffic management and control, both serving as examples of this structure, for all remaining categories refer to [10].

Table 1: Sub-categories and assigned systems of the category Navigation and traveller information

Navigation and traveller information	
Sub-categories	**Systems**
Electric cars	Electric Car Navigation System
Planning support systems	Multimodal Tour Planning System
Inland waterway information systems	Dynamic information for skippers
Navigation, traveller information, and parking guidance	Static Navigation System
	Dynamic Navigation System
	Static Passenger Information
	Dynamic Passenger Information
	Real-Time Traveller Information System
	Car-Sharing and Ride-Sharing Information System
	Dynamic Parking Guidance System

Table 2: Sub-categories and assigned systems of the category Traffic management and control

Traffic management and control	
Sub-categories	**Systems**
Signal control	Adaptive Signal Control
Highway systems	Junction Control System
	Road Section Control System
	Collective Re-Routing System
Railway systems	European Rail Traffic Management System
Enforcement systems – speed	Automated Speed Enforcement
Enforcement systems – weight	Automated Weight Limit Enforcement by Weigh-In-Motion
Inland Waterway systems	River Information Services (RIS)

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FROM QUALITATIVE ASSESSMENT TO A MODELLING FRAMEWORK FOR QUANTIFICATION

An ex-ante system assessment requires the use of models which are able to capture the effects of systems with their functionality either defined or anticipated. Models are also helpful in transferring results from (field operational) tests to larger areas or different contexts. Three major model categories are needed in this context: transport demand models, traffic flow models and emission models.

Transport demand models derive the transport demand from structural, economic, and behavioural data and provide it in the form of origin-destination-matrices. In macro models data and origins and destinations are aggregated to traffic zones, while micro models operate on individual actors. Due to their substantially different decision criteria freight and passenger transport are commonly modelled separately and merged in the road assignment process (freight and passenger vehicles on the same network).

Traffic flow (or traffic simulation) *models* simulate the behaviour of vehicles or travellers in the network (roads, tracks, waterways). Macro models are based on fundamental correlations between traffic volume, density and speed and, thus, depict traffic flow as a continuum. Micro models reflect the behaviour of individual drivers (vehicle following theory). Mesoscopic approaches exist which simulate individual vehicles, but which are based on aggregated parameters. They are considered macroscopic for the presented context.

Emission models derive energy demand and emissions from the traffic flow. Microscopic models can reflect the individual driving behaviour and detailed driving dynamics. Macroscopic models use simplified driving cycles to derive emissions. Emissions can also be modelled by simple factor approaches.

Which of these models are necessary depends on the system. The required functionality (including sensitivities) of the models is derived from the potential effects as they have been analysed above. In this way three steps are required for the assessment: a qualitative ITS assessment along the lines described before, the selection of required models, and the connection of the models with their required input data.

Application to examples

The effects indicated above for dynamic navigation systems underline the need for using all three model types: demand, flow and emission models. Because effects on driver behaviour are unlikely, a macroscopic modelling approach will be sufficient. Thus, also emission changes can be estimated on macroscopic level. This approach can be depicted as in Figure 5 (a).

Road section control systems influence driver behaviour, which necessitates the use of microscopic flow models. Effects on demand relate mainly to alternative routes or modes. Macroscopic demand models are sufficient for modelling of this kind of effect. If no feasible alternatives for the scrutinised road section exist, demand might even be regarded as fixed, making demand modelling dispensable as indicated in Figure 5 (b). Emissions can either be modelled microscopically or macroscopically.

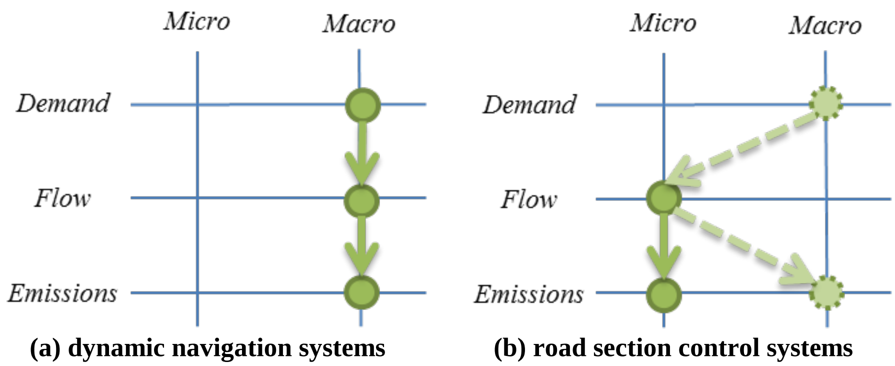

Figure 5 Model types required for system assessment

Details on the modelling framework and the relevance of open interfaces between models can be found in [24].

The large benefit of the described approach is not only the facilitation of ITS appraisal, but also the higher transparency in achieving comparable and reliable results from an assessment. The analysis of effect chains elucidates the requirements on the employed models and their input data.

A generic assessment methodology

The described approach serves as the foundation for a generic assessment methodology as it is described in [1]. The relevance of models for the assessment of ITS and how the required model types and characteristics can be identified has been explained above. The application of the methodology involves further steps as has been mentioned in the beginning. These steps, based on the analysis of effect chains of ITS, are documented in user friendly format with background information on a wiki style website [25]. The methodology has been applied to different real world scenarios in related projects and will be incorporated in running European projects. The application in related projects was a first step in validation. Based on the feedback from the projects the methodology has been adjusted. A second validation step was taken by assessing the validity of the approach with ITS and modelling experts [26].

CONCLUSIONS

ITS are now an integral part of the transport infrastructure. This calls for reliable appraisals of their costs and benefits. CO_2 emission reductions are among the promising benefits. So far, however, the system assessments are mostly limited to assessments of specific systems and mostly conducted ex-post by field operational tests. No general and standardised methodology for the whole range of available or conceivable ITS for surface transport exists yet which addresses the needs of all stakeholders and enables the reliable comparison of different systems. A user needs assessment revealed the high expectations directed at such a standardised assessment methodology for the CO_2 effects of ITS. Reliability, transparency, and flexibility are among these expectations.

A systematic and generally applicable approach is required to address the user needs. The major challenge consists in modelling all potential effects of ITS with relevance for CO_2 emissions. The foundation for mastering this challenge is the identification of all potential effects and the derivation of modelling needs from this analysis. To this end the dissection of transport into processes and the systematic analysis of possible influences on these processes is suggested.

Transport processes relate to transport demand (trip generation, route and mode choice etc.) and driver behaviour (choice of speed, driving dynamics, lane etc.). Together these processes lead to traffic flow in the network. Traffic flow causes emissions, depending on the vehicles and their condition (tyre pressure, auxiliary systems etc.). By following this effect chain (from transport processes to traffic flow to emissions), changes of emissions caused by the deployment of ITS can be estimated even ex-ante and in a transparent and general applicable way.

Transport processes are influenced by the available infrastructure, transport alternatives, and opportunities for activities among others. Also long-term effects can play a role (induced demand, changes in public transport scheduling etc.). ITS can have an impact on all these processes and the factors influencing them.

Based on existing categorisations and systems available and described in the literature, ITS are structured into systems with comparable expected effects. The effects are derived from literature reviews and expert consultations and led to the definition of 54 distinct systems in six categories and 24 sub-categories.

The qualitative system assessment based on the effect on transport processes facilitates the choice of required models to quantitatively estimate ITS effects. Three model categories are relevant: transport demand models, traffic flow models, and emission models. All models exist in macroscopic and microscopic variants with different functionalities and data needs. Models have to be combined to deliver the needed results. The qualitative system assessment provides the decision criteria for choosing the required model types.

The suggested framework presents the first important step towards a standardised assessment methodology for ITS. It enables appraisals of a wide range of systems from specialised systems for inland shipping to general dynamic navigation systems for travellers. Required sensitivities of models to changes of specific transport processes through the impact of ITS are elucidated. The validation of the methodology underlined that it follows a consistent and purposive process and is well described. However, major challenges in ITS assessment remain to be addressed. Namely how the mentioned sensitivities can be addressed in models or how the required input data can be obtained remains a challenge for many systems. The setting for further research into the assessment of systems is furnished, though, and the outline of a standardised assessment methodology is provided.

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REFERENCES

1. Mahmod, M., Jonkers, E., Klunder, G.A., Benz, T., Winder, A. (2015): The Amitran methodology framework for evaluating the impact of ICT-based measures on CO2 emissions in the transport field. Accepted for publication in IET Intelligent Transport Systems (September 2014).
2. Mans, D., Rekiel, Wolfermann, A., Klunder, G. (2012): User Needs for a Standardized CO2 Emission Assessment, Methodology for Intelligent Transport Systems. 19th ITS World Congress
3. Bristowa, A. L., Pearmana, A. D., Shiresa, J. D.(1997): An assessment of advanced transport telematics evaluation procedures. In: Transport Reviews: A Transnational Transdisciplinary Journal, Volume 17, Issue 3, pp. 177-205
4. Black, W. (1996): Sustainable transportation: a US perspective. In: Journal of Transport Geography, Volume 4, Issue 3, September 1996, pp. 151–159
5. Boltze, M., Schäfer, P.K., Wolfermann, A. (2006): Leitfaden Verkehrstelematik. Hinweise zur Planung und Nutzung in Kommunen und Kreisen (Transport Telematics Manual, Notes on Planning and Applications of ITS in Cities and Counties). Hrsg.: Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS). Berlin; Online at www.bmvi.de
6. ICT-Emissions (2013): Deliverable 2.1: Methodology. Available on http://www.ict-emissions.eu/wp-content/uploads/2012/05/D-2-1-Methodology-Final-04-06-2013_print.pdf
7. Gilka, Ph., Staubach, M. (2014): Fuel Efficiency Based on Eco Driving Information Systems. In: Proceedings of the 10th European ITS Congress, Helsinki, Finland, 16-19 June 2014
8. FESTA Handbook, available at http://www.fot-net.eu/
9. Ehrler, V. Davydenko, I., Ree, D. Ton, J. Auvinen, H., Lewis, A., Seidel, S., Lischke, A., Maurer, H. (2013): Standardized Emission Calculations along Supply Chains as a Basis for Smart Global Transport Solutions in a “Reality of Less” – Is an Approach within Reach? In: Transportation Research Record: Journal of the Transportation Research Board (TRR). 92nd Annual MeetingTransportation Research Board (TRB), 13.-17. Jan. 2013, Washington DC, USA
10. Amitran Consortium (2013). Deliverable 3.1: Methodology for classification of ITS. Amitran Project. Retrieved from www.amitran.eu.
11. Schick, P. (2003). Einfluss von Streckenbeeinflussungsanlagen auf die Kapazität von Autobahnabschnitten sowie die Stabilität des Verkehrsflusses (Impact of road section control systems on the capacity of highways and stability of traffic flow). Dissertation. Stuttgart
12. Geistefeldt, J. (2011): Capacity effects of variable speed limits on German freeways. Procedia - Social and Behavioral Sciences 16, (pp. 48–56).
13. Nissan, A., Koutsopoulosb, H.N. (2011): Evaluation of the Impact of Advisory Variable Speed Limits on Motorway Capacity and Level of Service. Procedia - Social and Behavioral Sciences 16, pp. 100–109.
14. Lee, C., Hellinga, B., Saccomanno, F. (2004): Assessing Safety Benefits of Variable Speed Limits. http://www.civil.uwaterloo.ca/bhellinga/publications/Publications/TRR%202004%20Assessing%20VSL%20(04-4835).pdf. Accessed 3 July 2014.
15. Wu Y., Lee P. (2007): The use of patent analysis in assessing ITS innovations: US, Europe and Japan. Transportation Research Part A. pp. 568-586
16. Bossom, R., Jesty, P. (2005): Different Types of ITS Architectures and Their Uses. In: Proceedings of the 12th World Congress on Intelligent Transport Systems. San Francisco
17. Toral, S., Torres, M., Barrero, F., Arahal, M. (2010): Current paradigms in intelligent transportation systems. In: IET Intelligent Transport Systems, Volume 4, Issue 3, pp. 201 - 211

18. U.S. Department of Transportation, Federal Highway Administration (2001): Intelligent Transportation Systems Benefits: 2001 Update (2001). Prepared by Mitretek Systems.
19. Toffolo, S., Morello, E., Samaras, Z. et al. (2014) ICT-emissions methodology for assessing ITS and ICT solutions. Proceedings of the Transport Research Arena 2014, Paris
20. Spence A., Turksma S., Schelling A., Benz T., Medevielle J.-P., McCrae I., Jaaskelainen J. and Boethius E. (2009): Methodologies for assessing the impact of ITS applications on CO2 emissions. Technical Report V1.0. EC-METI Task Force.
21. Kompfner P., Reinhardt W. and Members of the Working Group ICT for Clean and Efficient Mobility (2008): ICT for Clean and Efficient Mobility – Final Report, Brussels
22. ECOSTAND (2011): Deliverable 2.1: Inception report and state-of-the-art review. Available on http://www.ecostand-project.eu/
23. ECOSTAND (2012): Deliverable 4.1: Preliminary findings and identification of main issues. ECOSTAND Deliverable 4.1. Available on http://www.ecostand-project.eu/
24. Amitran Consortium (2014). Deliverable 5.1: Specifications of interfaces. Amitran Project. Retrieved from www.amitran.eu.
25. Amitran Guidance Knowledge base, http://www.amitran.eu/knowledge-base
26. Amitran Consortium (2014). Deliverable 6.2: Evaluation results. Amitran Project. Retrieved from www.amitran.eu.