D3.2: Test cases for Validation and Verification

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Work package	WP 3: Analysis and structuring of ITS impacts
Task	Task no. 3.4: Validation benchmark

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Abstract	The aim of the Amitran project is to develop a framework for evaluation of the effects of ICT measures in traffic and transport on energy efficiency and CO2 emissions. This deliverable reports on the outcomes of Task 3.4. Task 3.4 contributes to the validation and

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	The research leading to these results has received funding from the European Union Seventh Framework Programme under grant agreement n° 287551. FP7-ICT-2011-7: Information and Communication Technologies Low carbon multi-modal mobility and freight transport

	verification of the Amitran methodology by using test cases. For each test case the different steps in the methodology are described, including the choices that are being made and the 'path' that is followed through the methodology. From the test cases a generalization to all system categories is made, and the subcategorisation of systems is improved and aligned with the modelling approach.

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Control sheet

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Executive summary

The aim of the Amitran project is to develop a framework for evaluation of the effects of ICT (Information and Communications Technology) measures in traffic and transport (also called: ITS or Intelligent Transport Systems) on energy efficiency and CO_2 emissions. This report (Deliverable 3.2 of the Amitran project) describes the outcomes of Task 3.4. Task 3.4 contributes to the validation and verification of the Amitran methodology by applying it to six test cases, one from each ITS system category. For each test case the different steps in the methodology are described, including the choices that are being made and the 'path' that is followed through the methodology. From the test cases a generalization to the whole ITS system category is made, and the subcategorisation of systems is improved and aligned with the modelling approach. By carrying out this task also the ease of use of the framework is investigated.

The goals of this deliverable are (1) to verify the typology of ITS applications (categorisation and subcategorisation of systems), (2) to verify the set-up of the Amitran methodology, (3) to bridge the gap between theory (current description of methodology and framework architecture) and practice (applying the methodology and framework architecture as desktop research in preparation for the real world validation in WP 6), (4) to provide input to the validation on different types of cases and (5) to provide examples for the online guidance tool and checklist. The following steps were taken to reach these goals:

- Selection of test cases
- Development of template
- Filling in templates for test cases
- Review of (sub)categorisation

Reporting

Verification and validation of Amitran by applying models to real world examples is conducted in WP 5 and WP 6 respectively. The test cases used in Task 3.4 are, hence, to some extent generic in order not to limit the proof of concept to very specific scenarios. Effects of ITS are, in this deliverable, not necessarily based on proven effects, but also on *potential* effects. Thus, the Amitran concept is tested on a broad basis also considering systems which have not yet undergone field operational tests for their effects on CO_2 emissions. An overview on all test cases, use cases and real world scenarios employed in the course of Amitran is provided in this deliverable.

To test the Amitran methodology as explained above in this deliverable the following six test cases were chosen (one from each ITS system category, and aligned with WP 5 and WP 6):

1. Smartphone application with real-time personal travel information
2. Dynamic traffic light application (also called Adaptive Signal Control)

3. Electronic Toll Collection
4. Autonomous Driving
5. Dynamic Schedule Synchronization
6. eCall

Based on the work done in Task 3.4 a new subcategorisation of systems is proposed when looking at how the assessment on CO_2 effects should be carried out, see Table 1 hereafter. It has been investigated whether an assessment for CO_2 effects could take place in the same way for all the systems within one (sub)category. If not, a subcategory is added for the Amitran methodology, such that our methodology offers a consistent approach for each of the (sub)categories. In bold italics the changes compared to the original typology are indicated: new subcategories are added or existing subcategories are split into two. In red italics the six test cases are indicated.
The results in this report are mainly of use for the Amitran consortium and can be used by WP 6 as an addition to the validation and verification work that takes place there, and by WP 7 as content for the online guidance tool and checklist. For people from outside the consortium the online guidance tool and checklist that will be delivered at the end of the project will be of importance. This document is a step towards the Amitran online guidance tool and checklist.

Table 1: Categories, subcategories and systems for assessment in groups (in bold italics the changes compared to the original typology).

Main category	Subcategory	System
Specialised navigation, information, and planning support	***Electric cars***[1]	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***	***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***
Traffic management	Signal control	*Adaptive Signal Control*

[1] In the future, when the electric car radius of action increases, the number of charging station increases and charging times decrease, electric cars probably do not need a separate subcategory any more.

Main category	Subcategory	System
and 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
Demand and access management	***Electronic Fee Collection – toll***	*Electronic Toll Collection*
	Electronic Fee Collection – ticketing	Electronic Ticketing
	ITS Supported Measures	Restricted Traffic Zones Access Pricing Road Pricing
Driver behaviour change and eco-driving	***Driving Assistance including cruise control & Driving Behaviour – recognition system***	Intelligent Speed Adaptation/Assistance Green Light Optimised Speed Advisory Adaptive Cruise Control Predictive Cruise Control Cooperative Adaptive Cruise Control *Autonomous Driving* Lane Change Assistance System Parking Assistance System Driving Behaviour Recognition System
	Driving Behaviour – tachograph	Digital Tachograph
	Railway Systems	Driverless Train Operation Energy Efficient Train Driving System
Logistics and fleet management	Public Transport Systems	Computer Aided Dispatch and Scheduling Operational Control System *Dynamic Schedule Synchronisation*
	Freight Transport Systems – management & planning	Electronic system for freight transport Fleet Management System Supply Chain Management System
	Freight Transport Systems – truck parking	Intelligent Truck Parking
	Freight Transport Systems – terminal	Terminal Management System

Main category	Subcategory	System
Safety and Emergency	***Augmented awareness – event-based***	Collision Warning System Cooperative Intersection Collision Avoidance System Drowsy Driver Warning System Lane Departure Warning System Vehicle-based Pedestrian Detection System
	Augmented awareness – continuous	Night Vision System Weather Information System
	eCall	*eCall*
	Inland waterway systems	River Calamity Abatement Support

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1. Introduction

1.1 Goal

The aim of the Amitran project is to develop a framework for evaluation of the effects of ICT (Information and Communications Technology) measures in traffic and transport (also called: ITS or Intelligent Transport Systems) on energy efficiency and CO_2 emissions. This report (Deliverable 3.2 of the Amitran project) describes the outcomes of Task 3.4. Task 3.4 contributes to the validation and verification of the Amitran methodology by applying it to six test cases, one from each ITS system category. For each test case the different steps in the methodology are described, including the choices that are being made and the 'path' that is followed through the methodology. From the test cases a generalization to the whole ITS system category is made, and the subcategorisation of systems is improved and aligned with the modelling approach. By carrying out this task also the ease of use of the framework is investigated.

The goals of this deliverable are the following:

- Verification of the typology of ITS applications;
- Verification of the set-up of the methodology (proof of concept);
- Bridging the gap between theory (current description of methodology and framework architecture) and practice (apply the methodology and framework architecture as desktop research in preparation for the real world validation in WP 6);
- Providing input to the validation on different types of cases;
- Providing examples for the online guidance tool and checklist.

This task does not include modelling, but was conducted as a 'dry run'. The final validation of the methodology using cases with real data is conducted subsequently in WP 6. In order not to limit the proof of concept to very specific scenarios, the effects considered in this task are not necessarily proven by real world application and documented in the literature. Some effects might be speculative. Only thus, the test can ensure that Amitran will be able to also assess these potential effects, as Amitran aims at being applicable to new, yet not known or foreseeable systems.

The results of Task 3.4 will be used by WP 5 for the finalization of the requirements for the model interfaces and technical specifications, by WP 6 to prepare the validation of the methodology and by WP 7 as input for the online guidance tool and checklist. WP

1.2 Approach

This paragraph describes the approach and the steps that were taken to reach the goals mentioned in the previous section. It is indicated in which steps the different goals are reached. Because this is a relatively small task (compared to the overall project) a very practical approach is chosen.

1. *Selection of test cases*
   Six test cases (ITS applications) were selected, one from each main system category. In the selection the cases used in WP 5 and WP 6 were taken into account, so that they cover the needs from the three WPs and no double work is done.
2. *Development of template*
   A template is made with questions to be answered for the test cases. These questions cover the different parts of the methodology: types of effects that are expected, path through the flowchart, input data for the models, method for scaling up, and scenarios. At the end there are two questions about the other systems in the system category, and systems for which the assessment would be done in the same way.
3. *Filling in template for test cases*
   For the six test cases, the template is filled in.
   This step contributes to the verification of the set-up of the methodology, bridging the gap between theory and practice, provides input to the validation and provides examples for the online guidance tool and checklist.
4. *Review of categorisation*
   In a meeting, the results of the templates are discussed, especially the similarities and differences between systems within a system (sub)category. The system subcategorisation is reviewed from the point of view of the assessment.
   This step contributes to the verification of the typology of ITS applications.
5. *Reporting*
   Results from Task 3.4 are reported in this deliverable.

All activities are carried out internally within the consortium by the project partners. Collaboration with external projects was not expected in this task, this is taken up in WP 6.

1.3 Relations with other work packages and deliverables

This task has the following relations with other work packages and deliverables in Amitran:

- WP 3 and D3.1: review of the system (sub)categorisation based on how an assessment is carried out for different types of systems.
- WP 4 and D4.1: feedback on the methodology and flowchart.

- WP 5: alignment of test and use cases to finalize the requirements for the model interfaces and technical specifications
- WP 6: Task 3.4 serves as a dry run for the validation and preparation for the validation use cases.
- WP 7: outputs of Task 3.4 are content for the online guidance tool and checklist.

1.4 Overview of test cases, use cases and real world scenarios in Amitran

To make the Amitran methodology user friendly, relevant and valid, at different stages in the project examples (cases) were used to check the framework against relevant scenarios/systems. Namely in WP 3, test cases were used to check the Amitran framework for completeness, in WP 5, use cases served a check of the model interfaces, and validation use cases are outlined in WP 2 and employed in WP 6 for the validation of the complete Amitran methodology. While the cases used in WP 3 and WP 5 were of a theoretical nature and used internally, WP 6 builds upon real world projects and interacts with external stakeholders.
For highlighting the similarities and differences of the different cases used in Amitran, this section summarises the respective purposes and lists the concerned systems.

1.4.1 Test cases for framework checking (WP 3)

Deliverable 3.2 documents the application of the Amitran methodology (in a 'dry run') to six test cases (cf. Chapter 3), each coming from one of the (original) system main categories (cf. D3.1). It is investigated whether an assessment for CO_2 effects could take place in the same way for all the systems within one subcategory. For each test case the way in which the assessment should be carried out is described, using a template with questions. These questions cover the different parts of the methodology: types of effects that are expected, path through the flowchart, input data for the models, method for scaling up, and scenarios. It is described whether the Amitran methodology is applied in the same way for the different systems in the category, and what the differences are.
The main selection criterion for the test cases is to cover all system categories. Table 2 gives an overview of the systems serving as a test case.

Table 2: Overview of systems serving as a test case in WP 3.

Test case	Category	Modes[2]	Brief description
Smartphone	Navigation,	B, C, P,	A mobile (vehicle mounted or portable) online

[2] Mode can be Bike (B), Car (C), Pedestrian (P), Public Transport (PT), Ship (S) or Train (T).

Test case	Category	Modes[2]	Brief description
application with real-time personal travel information	traveller information, and parking guidance	PT	Navigation system which receives up to date (dynamic) traffic information and displays it on the map and/or considers this information in route suggestions.
Dynamic traffic light application (also called Adaptive Signal Control)	Traffic management and control	B, C, P, PT	Dynamic traffic light is traffic signal control with signal programs adapted to current traffic conditions with aiming at different goals like queue length limitation, emission reduction, public transport priority, etc.
Electronic Toll Collection	Demand and access management	C	The term Electronic Toll Collection subsumes all systems which collect road fees by electronic devices instead of conventional toll booths. The effect on CO_2 emissions derives from the nonnecessity to stop the car and must be separated from the effect a toll has in itself, e. g. Road Pricing.
Autonomous Driving	Driver behaviour change and eco-driving	C	Autonomous Driving refers to systems enabling a vehicle to drive automatically without any human input, either under certain traffic and environmental conditions (e. g. platooning) or the system performs the complete trip without human interaction.
Dynamic Schedule Synchronization	Logistics and fleet management	PT	The system synchronises dynamically the departure times of public transport to ensure a smooth transfer of passengers.
eCall	Safety and Emergency	C	In the event of an accident, the system initiates automatically a call to an emergency centre with the aim of reduced reaction times for emergency services.

1.4.2 Use cases for interface checking (WP 5)

In Task 5.1 of WP 5, the Amitran methodology is applied to nine use cases. The use cases describe how the influenced and non-influenced traffic can be modelled. In particular, they describe the functionality that should be provided by the relevant interfaces within the Amitran scope.

The use cases were selected such that they cover a wide range of interfaces. The following criteria were used to characterise this range:

1. ITS category
2. transport mode: road, rail, water or multimodal
3. dedicated freight system
4. factors and parameters that the ITS influences (cf. D3.1)
5. real world or theoretical use case

An overview of selected use cases, a brief description with respect to the selection criteria as well as the covered interfaces can be found in Table 3 (for more information, refer to [3]).

Table 3: Overview on use cases used in WP 5.

Use case	**Category**	**Modes**[3]	**Brief description**
Dynamic Navigation System	Navigation, traveller information, and parking guidance	C	A mobile online navigation system which displays up to date (dynamic) traffic information on the map and/or considers this information in route suggestions. The application directly affects *pre-trip mode planning and on-trip mode choice, (pre-trip) departure time planning and choice*, and *pre-trip and on-trip route planning and choice*. Covered interfaces are: Demand ⇨ Traffic Simulation Traffic Simulation ⇨ Emission Traffic Simulation ⇨ Demand
Real-Time Traveller Information System via Variable Message Signs	Navigation, traveller information, and parking guidance	B, C, P, PT	A system which provides route information to road users at strategic locations on the network; it directly affects only *on-trip route choice*. Covered interfaces are: Demand ⇨ Traffic Simulation Traffic Simulation ⇨ Emission Traffic Simulation ⇨ Demand
Adaptive Signal Control	Traffic management and control	B, C, P, PT	Adaptive Signal Control is traffic signal control with signal programs adapted to current traffic conditions with aiming at different goals like queue length limitation, emission reduction, PT priority, etc. The examined real world application affects *long-term route planning*, *on-trip route*

[3] Mode can be Bike (B), Car (C), Pedestrian (P), Public Transport (PT), Ship (S) or Train (T).

Use case	**Category**	**Modes**[3]	**Brief description**
			choice, and as a consequence *lane, speed, headway and driving dynamics*. Covered interfaces are: Demand ⇨ Traffic Simulation Traffic Simulation ⇨ Emission Traffic Simulation ⇨ Demand
Autonomous Driving	Driver behaviour change and eco-driving	C	Autonomous Driving refers to systems enabling a vehicle to drive automatically without any human input, either under certain traffic and environmental conditions (e. g. platooning) or for the complete trip. The application affects factors related to driving behaviour like *driving dynamics, speed, headway* and *lane choice*. It covers the interface Traffic Simulation ⇨ Emission.
Pay as You Drive	Demand and access management	C	The theoretical use case is a type of automobile insurance whereby the costs of the motor insurance are dependent upon type of vehicle used, measured against time, distance, behaviour and place. It will lead to a change in the driving behaviour of policyholder and therefore affect *traffic demand* and *speed*. As only one model is involved, no interface is needed.
Dynamic Parking Guidance	Traffic management and control	C	Such system guides drivers to available parking spaces, the researched system extend these function by the possibility to reserve and pay for a parking spot. It directly affects *destination choice* and *on-trip route choice* and addresses the following interfaces: Demand ⇨ Traffic Simulation Traffic Simulation ⇨ Emission
Energy efficient train driving	Driver behaviour change and eco-driving	T	The system provides the train driver with a recommended speed level as well as further driving style information like the time to start coasting. Therefore the system will affect *speed* and *driving dynamics*; no interfaces which are in the scope of Amitran.
Car sharing and ride sharing	Navigation and traveller information	C	Car Sharing is a system that allows the users to alternately use a vehicle, either with dedicated parking facilities (station based) or with the

Use case	Category	Modes[3]	Brief description
			possibility to left the car at the destination of the trip (free-floating). Ride Sharing is a similar service; but here not the cars themselves are shared but the "trips": a system user undertaking a trip declares this trip and other users joining in the vehicle. The system affects *the availability of transport means, choice of transport means, mode choice, trip generation* and *load factor/occupancy*. Covered interfaces are: Demand ⇨ Traffic Simulation Traffic Simulation ⇨ Emission Traffic Simulation ⇨ Demand
Dynamic information for skippers	Traffic management and control	S	Dynamic information for skippers is part of the River Information Services and aims to improve the reliability of travel times on inland waterways by providing shippers/planner with robust (accurate and timely) travel data on voyages and improving the estimation of travel times in route planning software. It can affect *strategic route planning*, *pre-trip route choice*, *on-trip route choice*, *strategic mode choice*, *speed* and *load factor*. Covered interfaces are: Demand ⇨ Traffic Simulation Traffic Simulation ⇨ Emission Traffic Simulation ⇨ Demand

1.4.3 Validation use cases (WP 6)

Amitran is regarded as a valid methodology, if it meets the user needs[4]. The validation of the Amitran methodology addresses, thus, a user perspective. The use cases for validation aim to describe in which contexts Amitran is going to be used or requested and are defined to understand the different environments which Amitran is expected to be applied in and to ensure that the validation process adequately addresses these application environments.

Use cases are based on the profile of the most relevant Amitran stakeholders, illustrating in which contexts and for which purposes Amitran might be applied. The resulting use cases aim to cover the broad range of potential users and stakeholders of Amitran. Because the validation use cases are conducted with real projects and external stakeholders, suitable

[4] For the verification of model interfaces refer to Deliverable 5.2.

projects had to be identified. Three projects with different level of collaboration were selected. Moreover, these projects are amended by surveys with external stakeholders (cf. Deliverable 6.2), see Table 4.

Table 4: Overview on use cases used in WP 6.

Use case	Category	Modes[5]	Brief description
COMPASS4D	Driver behaviour change and eco-driving	C	The project will examine cooperative services, in a field operational test, in particular Road Hazard Warning, Red Light Violation and Energy Efficiency Intersection Service. The use case will be applied to the methodology framework, the model interfaces, the scaling up methodology and the cost benefit analysis.
DRIVE C2X	Driver behaviour change and eco-driving	C	Similar to COMPASS4D the project will carry out field operational tests to assess cooperative systems with a focus on communication among vehicles and between vehicles and infrastructure. The collaboration includes the methodology framework, the model interfaces and the scaling up methodology.
DEN HAAG	Traffic management and control	C	The project focuses on traffic light optimization in a network. The use case will be tested against the methodology framework as well as, the model interfaces.
ICT Emissions	all	C	Similar to Amitran, ICT-Emissions developes a methodology to assess the impacts of ITS on CO_2 emissions with a focus on road transport.

1.5 Report overview

After this introductory chapter, the Amitran methodology and framework are briefly explained in Chapter 2. Chapter 3 describes the six test cases and the worked out examples by applying the Amitran methodology to the test cases, and makes a generalization to other systems within the same category. In Chapter 4 the conclusions can be found and after that the references are given.

[5] Mode can be Bike (B), Car (C), Pedestrian (P), Public Transport (PT), Ship (S) or Train (T).

2. Amitran methodology and framework architecture

In this chapter the most important aspects of the Amitran methodology and framework architecture, as reported in Deliverable 4.1 [2] of the project, are explained in order to understand the assessment process per category in the next chapters. For more details on the assessment methodology the reader is referred to [2] and [6]. For more details about scaling up, the reader is referred to [5].

Figure 1 illustrates the general outline of the ***Amitran methodology***: the chain from ITS systems to CO_2 emissions. The figure gives a logical overview of how ITS systems can have an impact on CO_2 emissions. The main elements of this chain are, from left to right, system categorisation, factors and parameters influenced by ITS, transport system, parameters relevant for CO_2 emissions and scaling up.

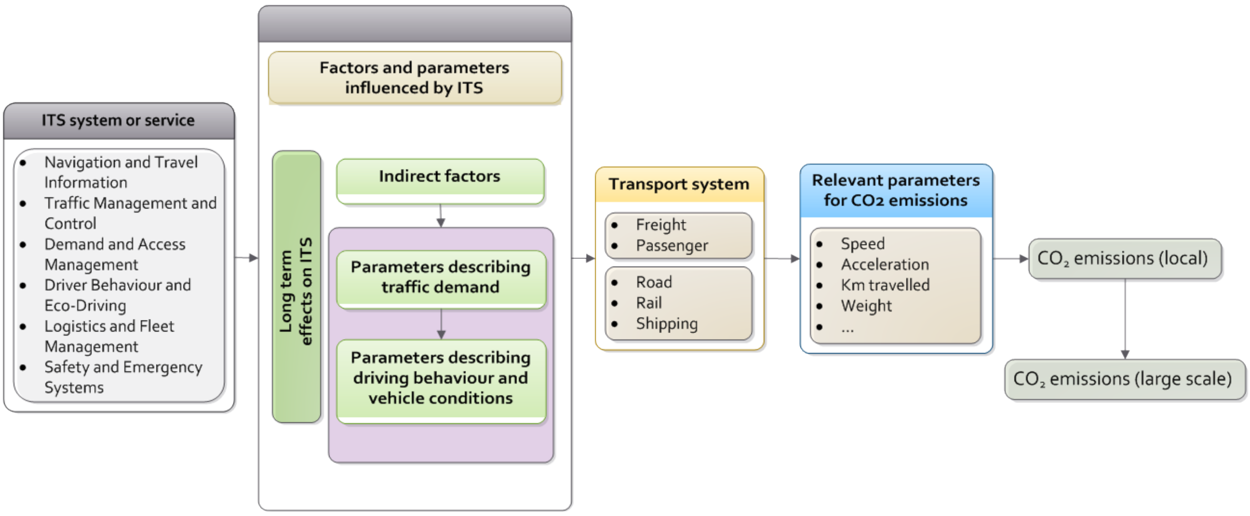

Figure 1: The chain from ITS systems to CO_2 emissions.

Starting from an ITS system, the system can have a direct and/or indirect influence on driver or traveller behaviour and on vehicle conditions which are relevant for CO_2 emissions. This is shown in Figure 1 in the second block. These direct and in direct influences can be described by factors and parameters which are defined in deliverable D3.1 of Amitran [1]. By separating the different types of effects of ITS, Amitran follows a new approach as compared to assessments done in the past. This approach offers a better understanding of the mechanisms by which ITS exert their influence. Together the direct and indirect influences are reflected in the overall transport system; the total of transport (freight and passengers) including all transport modes: road, rail and inland shipping. In turn, changes on the transport system have an effect on parameters that directly influence CO_2 emissions, such as speed, acceleration, kilometres travelled, etc. The CO_2 emissions on a local level can be calculated from these parameters by suitable available models and scaled up to a larger geographic region if needed. For scaling up two methods are distinguished: scaling up using statistics and scaling up using a macroscopic (multimodal) traffic model.

The ***framework architecture*** is a detailed and technical description of the required (modelling) steps in the Amitran methodology. The Amitran architecture follows the approach of the factors and parameters that can be influenced by ITS. This is done to keep the framework architecture (relatively) simple and consistent with the methodology, and because the choice of models and flow of calculations depend on the factors and parameters influenced by the ITS. Figure 2 shows the connection between parameters influenced by ITS and the framework architecture.

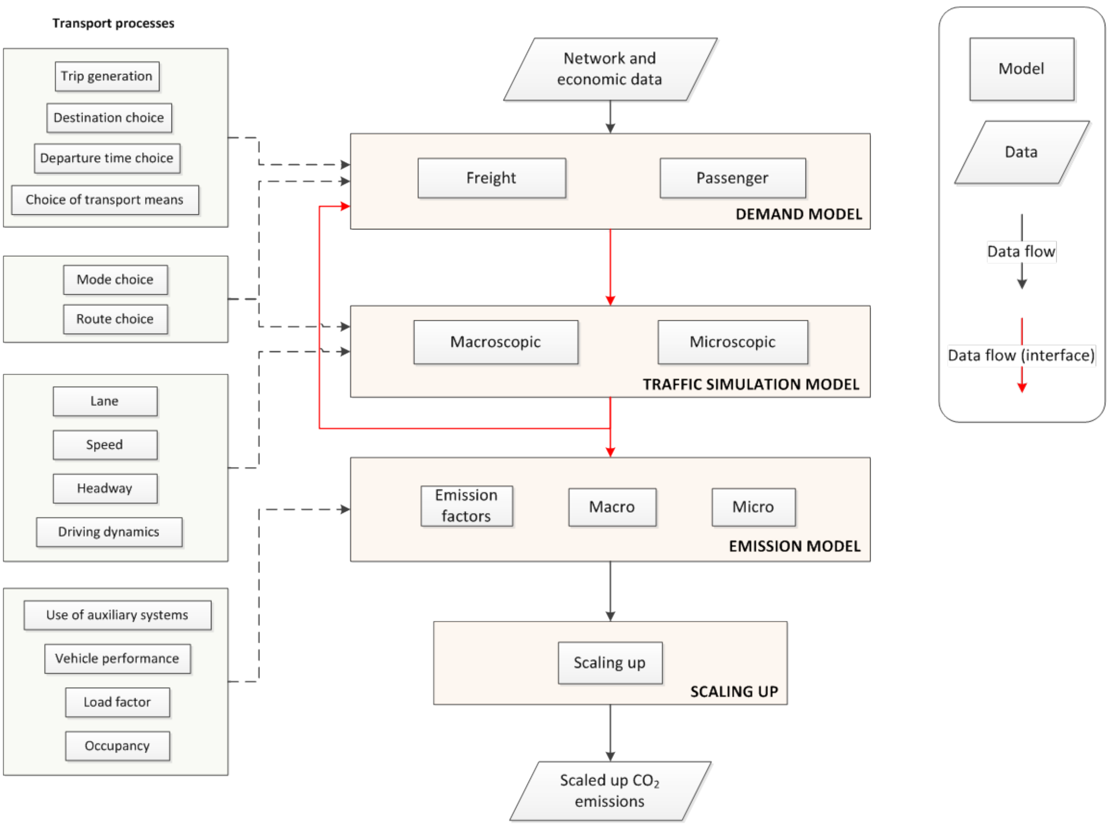

Figure 2: Connection between parameters influenced by ITS (on the left) and framework architecture.

3. Applying the Amitran methodology

In WP 3 of the Amitran project (reported in Deliverable 3.1 [1]) a system categorisation is made based on categories used in the ECOSTAND project. This categorisation can be found in Table 5.

Table 5: System categorisation Amitran (based on categorisation ECOSTAND project).

Main category	Subcategory
Navigation and Traveller Information	Navigation systems
	Traveller information systems
	Planning support systems
	Inland waterway information systems
Traffic Management and Control	Signal control
	Highway systems
	Railway systems
	Enforcement systems
	Inland Waterway systems
	Parking guidance
Demand and Access Management	Electronic Fee Collection
	ITS Supported Measures
Driver Behaviour and Eco-Driving	Driving Assistance including cruise control
	Railway Systems
	Driving Behaviour
Logistics and Fleet Management	Public Transport Systems
	Freight Transport Systems
Safety and Emergency Systems	Augmented awareness
	eCall
	Inland waterway systems

In Task 3.4 the Amitran methodology has been applied (in a 'dry run') to six test cases, each coming from one of the system main categories. After that a generalization has been made to all the subcategories (and sometimes even systems) within the same main category. It has been investigated whether an assessment for CO_2 effects could take place in the same way for all the systems within one (sub)category. If not, a subcategory is added for the Amitran methodology, such that our methodology offers a consistent approach for each of the (sub)categories.

In the next six sections, for each main category the following two topics are covered:

- For the test case the way in which the assessment should be carried out is described, using a template with questions. These questions cover the different parts of the methodology: types of effects that are expected, path through the flowchart, input data for the models, method for scaling up, and scenarios.
- It is described whether the Amitran methodology is applied in the same way for the different systems in the category, and what the differences are.

3.1 Navigation and Traveller Information

Navigation and Traveller Information systems are subdivided into four categories and nine subcategories, see Table 6. *Navigation systems* are based on maps to guide the user (driver, cyclist, pedestrian etc.) through the network. If the system provides up to date traffic information it is called dynamic. Navigation systems are divided into three subcategories, see Table 6. *Traveller information systems* exist in various formats and provide other types of information than for navigation of road traffic, e.g. public transport information, multimodal journey planning, and information about road works. Systems providing real time information on traffic flow or public transport schedules are again called dynamic. Systems limited to public transport information are referred to as passenger information systems. Systems can either be individual (personalised for the respective user) or collective (i.e. providing the same information to all users). Traveller information systems are divided into four subcategories, see Table 6. *Planning support systems* provide the information used by operators or decision makers to initiate measures or improvements to the transport system. Operators include public transport, traffic management or logistics operators and dispatchers.
Inland waterway information systems contain geographical, hydrological, administrative data and real time traffic information that are used by skippers and fleet managers to plan, execute and monitor journeys on waterways.

Table 6: Subcategories and systems in the category "Navigation and Traveller Information".

Navigation and Traveller Information	
Subcategory	**ITS Application**
Navigation systems	Static Navigation System
	Dynamic Navigation System
	Electric Car Navigation System
Traveller information systems	Static Passenger Information
	Dynamic Passenger Information
	Real-Time Traveller Information System
	Car-Sharing and Ride-Sharing Information System

Planning support systems	Multimodal Tour Planning System
Inland waterway information systems	Dynamic information for skippers

3.1.1 Test case: smartphone application with real-time personal travel information

Description of the system

A mobile (vehicle mounted or portable) online navigation system which receives up to date (dynamic) traffic information and displays it on the map and/or considers this information in route suggestions.

Effects of the system relevant for CO_2 emissions

The system has the following direct, short term effects:

- Departure time choice: A positive effect is assumed, since congestion can be avoided using the system by departing earlier or later. However, in a field operational test performed within the project TeleFOT, no statistically significant differences in departure times were discovered ([8], p. 63). As these results are accounted for the fact, that especially commuting trips are well optimized based on experiences, the system can still have an impact on rarely driven routes as well as when unexpected jams or delays occur ([8], p. 65f).
- Route choice: positive effect, since congestion can be avoided using the system by choosing a route with no or less congestion. Such system may change both peoples' route choice and the proportion of road types (e. g. highway vs. rural road) driven on, to a greater extent due to the navigation itself and to a lesser extent due to traffic information as discovered in field operational tests ([8], p. 61).
- Destination choice: small effect, one might change the destination when there is heavy congestion on the route to the originally preferred destination. This can however not always be done, often the destination is fixed (e.g. the working location or medical practice, etc.). This is not always necessarily a positive effect, since the new destination might be further away than the original one.
- Mode choice: one may decide to switch to public transport (pre-trip and on-trip) when the system indicates heavy congestion on the road such that travel times with public transport may become shorter than by passenger car, or one may decide to take the car when there is no congestion on the road. Several studies examined the influence of real time information on mode choice ([8], [11], [12]). Habit plays a major role in mode choice ([11], p. 8), but can be influenced to a different extent. By a survey, conducted on the Transport Direct multimodal journey planning website, it was figured out, that 7.7% of those users who had made the trip before intended to use public transport

instead of using their car, 2.3% vice versa ([12], p. 29). For commuter trips significant changes in car use could be discovered in some field operational tests, but the degree of these changes differs and is explained rather by a change in the economic status of the participants than the provided TeleFOT functions and information ([8], p. 54).

- Trip generation: one might decide not to leave at all when there is heavy congestion on the route to the destination, or to make an extra trip when there is no congestion on the route.

Besides the effects mentioned above, which already happen on the short term, additionally some long term effects can be expected. A small increase in traffic demand could be possible when the system would be able to remove congestion structurally. Also changes in public transport scheduling would be possible when the system would increase the use of public transport structurally.

There are only very small influences of the ITS system on other factors that could influence traffic demand:

- Positive: transport costs will be reduced when congestion is reduced
- Positive: connection with other transport modes may improve (alignment of times by making use of arrival time estimation).

Path through Amitran methodology

The following describes the path through the methodology flowchart and indicates which model categories are needed to be able to calculate CO_2 emissions:

Passenger demand model + Networks (road + public transport)
↓
Macroscopic flow model
↓
Link indicators
↓
Macroscopic emission model
↓
Emission data
↓
Scaling up

Input data

Input data needed for this case are:

- Network data: road network including public transport lines and scheduling.

- Structural data (economic data, count data and more, depending on the model) to derive the demand and calibrate the traffic model.
- User data for capturing the ITS effect: number of (active) users of the smartphone application, algorithms of the smartphone application (how is the routing advice determined etc.), user compliance data, such as when (with how many delay) do people decide to change their mode or departure time or route? Which route/mode/departure time do users and other people (comparison group or data of same persons before / after the introduction of the ITS application) choose, depending on the circumstances (reliability of the system might have an indirect effect on this)?

Scaling up

For scaling up, a direct method with statistics or modelling method – given that a macroscopic model on the required scale is available – are both possible. The preferred method depends on the scale one wants to scale up to. If the scaling up level is a city or region, using a traffic simulation model is feasible, and there is an opportunity to involve regional service providers who offer travel information in data acquisition. When results have to be scaled up to a large region (e.g. country) the preferred method is to use statistics, because applying a traffic simulation model for this system will probably be too complicated and too time consuming (route calculation, public transport scheduling etc.). This does not mean that using statistics is easily feasible. There are many challenges, such as the transfer of acceptance rates, incorporation of the reliability of the system, etc.

Scenarios

Important scenarios for this case are:

- Networks both urban and inter-urban (for short distances)
- Networks with many or few route alternatives
- With and without congestion
- Including possible changing points to public transport

3.1.2 Generalization to subcategories

Systems for which similar effects can be expected as for the test case and that can be treated similarly with regard to assessment are other systems within the subcategories ***Navigation systems and Traveller information systems***, such as real-time navigation systems (though mostly on-trip), internet websites with travel/traffic information (mostly pre-trip). For static navigation systems probably a simpler approach will satisfy. For these subcategories the type of input is the same, as well as the model categories that are needed to be able to calculate CO_2 emissions. For some specific system a distinction between road transport and public transport (tram, train, metro) might be needed. Whether it is a Navigation system or a Traveller information system does not matter that much for the type of assessment, since there is some overlap between the functioning of the systems that fall into these categories;

both categories deal with the route and mode of transport a traveller chooses. What is most decisive for the way the assessment is carried out is the type of information that is provided to the traveller and the way in which this information is provided. It differs a lot whether multimodal information is provided or just information for car driving (inclusion of public transport or not) and whether the navigation system is static (at the start of the trip the route is decided and will not change while travelling) or dynamic (the route might change on-trip). For Dynamic navigation systems a feedback loop is needed from the traffic state in the simulation to the implemented system, because for dynamic route choice on-trip information about the current traffic situation is needed and the influence this information has on the drivers' route choice needs to be taken into account. For Static navigation systems only a one-way link is needed, since the route advice will not change during the trip – a simple approach satisfies, as well as for Car-sharing and Ride-sharing information systems. In case of the latter the main change is in the number of kilometres driven. For that a traffic model is not necessarily needed, but a simple macro emission model can be used.

For ***Electric car navigation*** a model including information about charging (e.g. charging stations location and status) is needed, therefore Electric car systems need a new subcategory. In the future, when the electric car radius of action increases, the number of charging station increases and charging times decrease, electric cars do not need a separate subcategory, but for now it is kept that way.

Application of the Amitran methodology to ***Planning support systems*** is very different from Navigation and Traveller information systems, because it is about commercial transport, which is more complex, the logistics routes are normally designed on beforehand, and the driver behaviour has to be studied for a fleet with professional drivers, and not individual´s driver behaviour. For freight specific freight models are needed, and for public transport models that can handle public transport are needed. In the usual traffic models, these are not included. The same holds for ***Inland waterway systems***, for which waterway models are needed. For trains and ships, specific models exist. Also for freight, specific freight (transport) models exist, varying from models more suitable for the planning phase to models dealing with freight transport.

3.2 Traffic Management and Control

Traffic Management and Control systems are subdivided into six categories, see Table 7. In the category *Signal control* we only consider one subcategory, Adaptive signal control, which is traffic signal control based on online actuation. *Highway systems* are systems used primarily on highways. The systems are divided into the network element they affect (junctions, road sections, or routes in the network). These systems commonly use both traffic information and dynamic regulations to influence the traffic flow. The Railway system *ERTMS* is an EU "major European industrial project" to enhance cross-border interoperability and signalling procurement by creating a single Europe-wide standard for railway signalling. *Enforcement* *systems* combine detection/monitoring in order to fine (e.g. speeding or vehicles that are too heavy). *Inland waterway systems* aim for optimal utilization of the infrastructure and assurance of safe navigation on waterways. *Parking guidance systems* are systems which guides drivers to available parking spaces via variable signs or in-car information.

Table 7: Subcategories and systems in the category "Traffic Management and Control".

Traffic Management and Control	
Subcategory	**ITS Application**
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 (ERTMS)
Enforcement systems	Automated Speed Enforcement
	Automated Weight Limit Enforcement by Weigh-In-Motion
Inland Waterway systems	River Information Services (RIS)
Parking guidance	Dynamic Parking Guidance System

3.2.1 Test case: dynamic traffic light application

Description of the system

Dynamic traffic light (DTL) (also called Adaptive Signal Control) is traffic signal control based on online actuation. The signal programs and their elements are updated based on traffic information collected by local detectors and/or provided by a central computer. The actuation can aim at different goals (queue length limitation, delay reduction, emission reduction, etc.). Public transport priority can be included as a goal. The term adaptive signal control is used here in a general sense for all kinds of traffic actuated signal control like

- Systems for isolated intersections (local traffic actuation)
- Coordinated systems ("green wave", network solutions)
- Model based systems (i.e. systems deriving their actuation from real time traffic models, e.g. SCOOT, SCATS, MOTION, BALANCE)

Effects of the system relevant for CO_2 emissions

Concerning direct short term effects, dynamic traffic light will change the driving dynamics – this is seen as the purpose of Dynamic Traffic Light (DTL). Other factors are not affected primarily; through changes in capacity and/or travel times, induced secondary effects are possible. Also changes in route choice are possible: DTL can encourage drivers to choose certain routes by better synchronization and longer green times of the traffic lights.

Long term effects could result from the changes in capacity and/or travel times; this could lead to additional demand in the transport means mostly affected by DTL (cars). Depending on the realization, a shift in modal split can result (e.g. from public transport to car). However, this effect might be of lesser degree.

There are other factors that could influence traffic demand. Depending on the concrete realization/implementation and the system installed before, transport cost (through travel times) can be affected. Capacity in the network might remain the same (namely that of the intersection area), but the distribution to different traffic streams / transport means can change. There is a potential to dynamically adapt capacity to the (local area) demand.

The implementation of DTL and the experiences might in the future lead to more elaborate systems that dynamically influence traffic management and control.

Path through Amitran methodology

The following describes the path through the methodology flowchart and indicates which model categories are needed to be able to calculate CO_2 emissions:

Demand model + Networks (road only)
↓
Microscopic flow model
↓
Trajectories → Link indicators
↓ ↓
Microscopic emission model Macroscopic emission model
↓
Emission data
↓
Scaling up

With regard to the emission modelling there are two options. The trajectories resulting from the microscopic flow model may be passed on to a micro emission model or be aggregated and fed to a macro emission model. A "simple macro emission model" seems not appropriate.

Input data

Assumed is that the input for the base case (without DTL) is available. Then the input data needed for this case are:

- Network data: road network including traffic regulations (static as well as "dynamic" ones such as those used for any traffic management scheme).
- Data on the system, preferably the way it really operates (data, algorithms) and not via assumed changes to the network's parameters like link or intersection capacities (or assumed waiting times at intersections or the like). In the flow model, the traffic control

model is exchanged or adapted from the conventional one to the DTL. This input must be provided by the DTL implementer (e.g. city authority, manufacturers or consultants).

- User data for capturing the ITS effect: route choice (do people decide to change their route?). These data have to come from FOT, test or trial data, or assumptions have to be made.

Scaling up

For scaling up, none of the standard scaling up methods are applicable: DTL will always be very specific to the concrete situation with conventional control, with the network characteristic (how many alternative routes are possible?) and the realization (with or without information to drivers about influenced routes for adapting their routing decisions). Results for DTL should therefore always be linked to a concrete scenario. Alternatively, many scenarios should be elaborated with micro simulation, after which scaling up with statistics could be possible when sufficient data (on route alternatives, type of control, etc.) is available for all European (or national) cities. But it is unlikely that all these data will be available on short term.

Scenarios

Scenarios that are important for Dynamic traffic light applications, are:

- A concrete network with a concrete implemented traffic control. This is very much a standard use case for a microscopic traffic model.
- High density traffic (otherwise DTL has no advantage).

For scaling up also different urban network types with few or large number of route alternatives.

3.2.2 Generalization to subcategories

The test case described above is the only system (type) belonging to the subcategory ***Signal control***. The subcategory Signal control is different from the other subcategories in Traffic management and control considering how the assessment can be done. The closest type of system with regard to the assessment is a traffic flow control for motorways (ramp metering), like section control or more advanced systems like shockwave damping. Also routing information systems (collective rerouting) are partly comparable.

Going systematically through the other subcategories within Traffic management and control the following can be said about the assessment. Within the subcategory ***Parking guidance*** assessments are done in a way (partly) similar to Navigation systems (from Section 3.1). Personal parking guidance is more or less similar to personal navigation. 'Collective' parking guidance (parking guidance by signs next to the road) is more or less similar to collective rerouting through VMS. This brings us to the subcategory ***Highway systems***. Just as parking guidance, assessments for Collective re-routing systems are done in a way (partly) similar to Navigation systems and can be modelled macroscopically. The route choice model needs to be calibrated and validated, especially the routing behaviour in the reference case and the compliance to the re-routing advice. For the other two system types within the subcategory Highway systems, Junction Control Systems can be assessed with a microscopic traffic model using a network mainly consisting of motorways and a small part of the connecting urban network. Road section control systems have an effect on the speed distribution and should be assessed in different ways depending on the type of system: dynamic speed limits can be modelled macroscopically, dynamic lane assignment and dynamic shoulder use require microscopic modelling with lane change modelling.

The two system types within the subcategory ***Enforcement systems*** have to be treated differently with regard to the assessment. Automated speed enforcement has an effect on the speed distribution (there is an overlap between this system and road section control systems). Weight limit enforcement is different; a possible effect is that more trucks should be used because they may not exceed a certain weight. This may lead to an effect on the number of truck trips between an Origin-Destination pair. Therefore the two system types within the Enforcement systems subcategory should be kept separate for the Amitran methodology.

The subcategories ***Railway systems*** and ***Inland waterway systems*** are both very different from the other subcategories and from each other. Respectively railway models and waterway models are needed.

3.3 Demand and Access Management

Demand and Access Management systems are subdivided into two categories, see Table 8. In the category *Electronic fee collection* fall systems that use electronic forms of payment, for example for paying toll, public transport tickets and parking. *ITS supported measures* are measures which aim to restrict the demand and which are realised by means of ITS, such as road pricing with different price levels per road and/or time of day. With *ITS supported measures* not the payment system in itself is meant but the total system or mechanism to reduce the demand in a certain area or at a certain road (different from normal Electronic Fee Collection).

Table 8: Subcategories and systems in the category "Demand and Access Management".

Demand and Access Management	
Subcategory	**ITS Application**
Electronic Fee Collection	Electronic Toll Collection
	Electronic Ticketing
ITS Supported Measures	Restricted Traffic Zones
	Access Pricing
	Road Pricing

3.3.1 Test case: Electronic Toll Collection

Description of the system

The noun Electronic Toll Collection refers to a system for collecting road fees by electronic devices instead of conventional toll booths. Vehicles, hence, do not have to stop at the tolling facility. The effect on CO_2 emissions has to be separated from the effect a toll has in itself, e. g. Road Pricing.

Effects of the system relevant for CO_2 emissions

The implementation of Electronic Toll Collection will lead to the following direct, short term effects:

- A change in pre-trip route choice caused by a higher preference of route compared to the same route with toll booth only as less time is anticipated for the payment process.
- The parameter speed will be affected due to higher speed on ETC lanes compared to lanes with toll booth counters.
- To a lesser extent strategic and on-trip route choice will be influenced for the same reasons as pre-trip route choice is.
- Lane choice (ETC lane preferred) as well as headway and driving dynamics are also affected, depending on the system shorter headways are feasible and more frequent and potentially different deceleration/acceleration rates than in a toll booth lane may occur.
- On a long term perspective the ETC system increases attractiveness of a tolled route which might lead to induced traffic demand. Furthermore the system might influence the factors infrastructure capacity (will be improved) and the availability of transport modes, as parallel public transport services lose share and therefore will run a reduced schedule. Both factors could influence transport demand.

Path through Amitran methodology

The following describes the path through the methodology flowchart and indicates which model categories are needed to be able to calculate CO_2 emissions:

Demand model + Networks	
↓	↓
Microscopic flow model (local changes or broader scope)	Macroscopic flow model (broader scope)
↓	↓
Trajectories	Link indicators
↓	↓
Microscopic emission model	Macroscopic emission model
↓	
Emission data	
↓	
Scaling up	

Emission changes have to be distinguished between local changes at the tolling facility and changes on a broader scope due to changes in traffic demand and route choice. To evaluate local changes a microscopic traffic simulation model is required, which feeds into preferably a microscopic emission model. To calculate the emission changes on a broader scope either a microscopic flow model is needed to compute the changes in capacity, or simplified assumptions have to be made [7]. The changing capacities are the basis for a before/after comparison with a route assignment model (macroscopic sufficient). If long term effects on mode choice, departure time choice etc. are to be captured, a demand model is needed (a macroscopic scale is sufficient).

Input data

Depending on the intended emission scale (see above), the input data needed for this case are:

- OD matrix
- Capacity of lanes at tolling facility (or a model to compute it)
- Multimodal network data
- Data on the tolling facility, the way it operates/works
- User data for capturing the ITS effect: route choice, mode choice

Scaling up

For the local emission changes at tolling facilities the scaling up using statistical data should be sufficient, if the number of tolling facilities is known and used. For changes in emissions due to mode choice and route choice, the availability of alternative routes has an impact. If the observed changes for a local case are rather small, a simple factor per tolling facility might be a good approximation (again using the simple scaling up approach). If the change requires a more accurate approach, macroscopic modelling with adjusted tolling facility capacities would be necessary. The key is therefore a careful analysis of how crucial emission changes occurring away from the tolling facility are (indirect effects).

Scenarios

Scenarios that are important for Electronic Toll Collection applications are:

- The average vehicle mix at tolling facilities is important, because of the impact of changes in speed, acceleration and idling time. Engine types, size, or emission classes will vary.
- The location of tolling facilities.

3.3.2 Generalization to subcategories

There are only two subcategories within the main category Demand and access management. Electronic Toll Collection falls into the subcategory ***Electronic Fee Collection***. The other system type within this subcategory, Electronic Ticketing (for public transport), has a completely different effect and requires a totally different modelling approach. For Electronic Toll Collection, the assessment is quite similar to Junction control systems and Automated speed enforcement; they are all systems with a local impact on traffic flow that change capacity and, thus, route choice and other demand parameters.

The subcategory ***ITS supported measures*** is different from Electronic Fee Collection from the assessment point of view. Within the subcategory, there are some differences between the different system types, but how this works out for the assessment depends on the specification of the system.

3.4 Driver Behaviour and Eco-Driving

Driver Behaviour and Eco-Driving systems are subdivided into three categories, see Table 9. Two categories are specific for road traffic; the third for rail traffic.

Driver assistance and cruise control support the driver in controlling the speed of the vehicle or performing manoeuvres. The different systems can be distinguished by their purpose, the extent to which they intervene in the driving, and the communication with the infrastructure or other vehicles. *Driving behaviour systems* consist of Driving behaviour recognition systems and Digital Tachograph. *Railway systems* are ITS systems specific for train driving behaviour (for example advising on speed).

Table 9: Subcategories and systems in the category "Driver Behaviour and Eco-Driving".

Driver Behaviour and Eco-Driving	
Subcategory	**ITS Application**
Driving Assistance including cruise control (road traffic)	Intelligent Speed Adaptation/Assistance
	Green Light Optimised Speed Advisory (GLOSA)
	Adaptive Cruise Control (ACC)

	Predictive Cruise Control (PCC)
	Cooperative Adaptive Cruise Control (CACC)
	Autonomous Driving
	Lane Change Assistance System
	Parking Assistance System
Railway Systems	Driverless Train Operation
	Energy Efficient Train Driving System
Driving Behaviour (road traffic)	Driving Behaviour Recognition System
	Digital Tachograph

3.4.1 Test case: Autonomous Driving

Description of the system

Autonomous Driving systems enable the vehicle to drive automatically without human control. This means that no input is needed from a human to control the vehicle. Two categories of autonomous driving can be considered for this ITS:

- Conditionally autonomous driving: the full control is given by the driver to the system under certain traffic and environmental conditions, recovering it when these conditions change (e.g. platooning).
- Fully autonomous driving: the driver initially provides the destination and no other input is expected by the system; the system performs the complete trip without human intervention.

Another level of automation exists: the assisted driving, in which the driver transfers to the system certain functions in specific situations, but the human keeps monitoring is responsible for safety.

Effects of the system relevant for CO_2 emissions

The system produces the following direct short term effects:

- On-trip, autonomous driving is safer than the manual driving, the speed can be controlled depending on the traffic flow or the speed limits, the distance between the vehicles is maintained taking into account the speed, and the system can adjust the driving dynamics, avoiding unnecessary acceleration and braking actions.
- Route choice effects in case the system also needs road equipment.

The long term effects are the following:

- Effects on freight transport are expected, since the autonomous driving system, will open new capabilities for a better synchronization of vehicles and routes to perform a more efficient transport of goods. What exactly the effects will be is not sure. Other advantages for freight transport are that less resting time is needed for the drivers and more flexible transport chains become possible.

- Autonomous driving has a very high influence on factors that could influence traffic demand:
  - The infrastructure capacity will increase because of a more homogeneous speed and a more reduced headway.
  - In addition, accidents and induced traffic jams will be also minimized as primary effects.
  - Road trains will be the most efficient way to drive along the roads, this will reduce aerodynamic resistance that leads to less fuel consumption and therefore transport costs.

Path through Amitran methodology

The following describes the path through the methodology flowchart and indicates which model categories are needed to be able to calculate CO_2 emissions:

Demand model + Networks (road only)	
↓	
Microscopic flow model →	Macroscopic flow model
↓	↓
Trajectories	Link indicators
↓	↓
Microscopic emission model	Macroscopic emission model
↓	
Emission data	
↓	
Scaling up	

The preferred way to carry out the assessment is to go from demand model to microscopic traffic model and then to emission model. This is the most precise way; it includes effects like reduced drag and optimized trajectories. An alternative is to go from microscopic to macroscopic traffic modelling and then to a macroscopic emission model. This alternative can simulate larger scenarios, but lacks some aspects of the emission calculations.

Input data

The input data needed for this case are:

- Network data: road network, OD data
- Data on the system: how does it work, does it need dedicated lanes/roads, etc.
- User data:
  - For knowing when the user turns the system on and off, in what situation, and what the settings are he or she uses.
  - For demand modelling: do people change their mode, departure time or route because of the system?

Scaling up

For the emissions and energy consumption related to individual vehicles the usage of statistical data will be needed. For the macroscopic model a simulation model is required, in which it is possible to modify the conditions according to the specific aspects of the region or country studied. This is necessary because the autonomous driving is currently in research phase and it is not possible to get all the required data from the real situations.

Scenarios

Scenarios depend on the concrete implementation of autonomous driving. They have to reflect the requirements (dedicated lanes versus existing road infrastructure, what environment, urban roads versus motorway only). The usage of the roads required (traffic flow, traffic demand, vehicle types,…) will set a current baseline. With regard to the baseline scenario, the most logical is to compare the same routes with and without platooning.

3.4.2 Generalization to subcategories

Autonomous Driving falls into the subcategory ***Driving Assistance including cruise control***. The system is very different from the other systems in the subcategory, since it takes over the driving task. However, it can be modelled in the same way (with the same type of models) as the other systems in this subcategory.

The subcategory ***Driving Behaviour*** includes two types of systems. For Driving Behaviour Recognition Systems the assessment is similar to that of Driving Assistance systems. For the Digital Tachograph a different type of assessment is done since this involves freight modelling.

The subcategory ***Railway Systems*** requires a different type of assessment because of the need to use railway and train models.

3.5 Logistics and Fleet Management

Logistics and Fleet Management systems are subdivided into two categories, see Table 10: public transport systems and freight transport systems.

Table 10: Subcategories and systems in the category "Logistics and Fleet Management".

Logistics and Fleet Management **Subcategory**	**ITS Application**
Public Transport Systems	Computer Aided Dispatch and Scheduling (CADS)
	Operational Control System (OCS)
	Dynamic Schedule Synchronisation
Freight Transport Systems	Electronic system for freight transport
	Fleet Management System (FMS)

	Intelligent Truck Parking
	Supply Chain Management System
	Terminal Management System

3.5.1 Test case: Dynamic Schedule Synchronization

Description of the system

A Dynamic Schedule Synchronization system can be a subsystem of an Operational Control System (OCS). These systems serve the purpose of optimising operational control by utilising dynamic operational data to assure punctuality and precise connection times and improve the allocation, rotation and maintenance of vehicles online. Such a system is operated in a public transport control centre and can include several subsystems like communication to the drivers, passenger information provision as well as a Dynamic Schedule Synchronization System.

Such a dynamic schedule synchronization system in particular synchronises dynamically the departure times of public transport services to ensure a smooth transfer of passengers. Due to its specific functionality it is treated as a separate system.

Effects of the system relevant for CO_2 emissions

Concerning direct short term effects, the system will influence the departure time choice, as there is no or less buffer time necessary for connections with a transfer. Therefore a passenger might start the trip later. Route choice (strategic, pre-trip as well as on-trip) can be affected too, as people might choose routes with interchanges instead of direct, more time consuming connections due to a higher reliability of transfer connections.

Long term effects can be a change in strategic mode choice due to a higher reliability of public transport (e. g. from car to public transport) or a change in public transport scheduling. The latter one can be a result of:

- An increase in public transport share entailing an increase of scheduled trips
- A change in the whole public transport network by shifting trips from direct, but longer connections to short ones terminating at an interchange station
- Extended scheduled journey times to include an average waiting time at interchanges

Other factors that could influence traffic demand:

- Transport costs: due to changes in public transport scheduling, the public transport provider might decide to adjust fares, i.e. changes in transport costs for the passengers.
- Connection with other transport modes: this is what the system is intended to change inside of public transport. The average waiting time at interchanges will decrease and the unpredictability (in models expressed as a penalty for changing modes) will be less.

Rebound and indirect effects, which are expected to a lesser extent, can be:

- A shift in mode choice caused by less congestion due to a higher share of public transport
- A change in mode and route choice because of longer journey times for passengers not transferring, caused by an average waiting time at interchanges.

Path through Amitran methodology

The following describes the path through the methodology flowchart and indicates which model categories are needed to be able to calculate CO_2 emissions:

Freight & passenger demand model + Networks (road + public transport)
↓
Macroscopic flow model
↓
Link indicators
↓
Macroscopic emission model
↓
Emission data
↓
Scaling up

Only a change in mode choice is expected to have an impact on CO_2 emissions. Therefore a multimodal transport supply model as well as a passenger demand model are needed, both on a macroscopic level. The macroscopic traffic flow model has to include a calculation or an assumption on average waiting times at interchanges. For example, waiting time on interchanges can be calculated as the scheduled waiting time plus percentage of missed connections multiplied by the headway of trains (or buses). With an implemented system the average waiting time will decrease due to a decrease of the percentage of missed connections and, hence the travel time will decrease which in turn will lead to a change in modal split.

Input data

The input data needed for this case are:

- Network data: multimodal network, OD data
- Public transport schedule data
- System specifications

Scaling up

Both scaling up methods can be used, depending on the availability of models and statistical data. The severity of effects on CO_2 emissions depends on the public transport schedule (dense headway or not), amount of travellers affected by the system, area (urban vs. rural) and distances. Therefore modelling with a macroscopic model is preferred.

Another way of reasoning could be that the effects on CO_2 emissions caused by this system are rather small, so the method that requires the least effort (statistics method) is recommended.

Scenarios

Scenarios that are important for Dynamic Schedule Synchronization are:

- Different parts of the day (peak hour, night), days of the week (Monday – Friday; Sunday and public holiday).
- Different areas, as in urban networks more route choices are available compared to rural areas. Areas with different levels of public transport (how many options, good alternative for the car, densely populated or not, etc.) should be considered.

3.5.2 Generalization to subcategories

Dynamic Schedule Synchronization (the test case) falls into the subcategory ***Public Transport Systems***. Other systems within this subcategory are Computer Aided Dispatch and Scheduling and Operational Control System and they serve the purpose of optimizing public transport and increasing punctuality and reliability. Therefore an effect on mode choice is expected which can be modelled in the same way as the system Dynamic Schedule Synchronization.
The other subcategory within Logistics and fleet management is ***Freight Transport Systems***. They are of a very different nature than Public Transport Systems and have to be assessed in another way. Also the systems within this subcategory cannot be all treated in the same way. Electronic system for freight transport (e-Freight), Fleet Management System and Supply Chain Management System deal mostly with management and planning at freight companies, so insight and models for that are needed in the assessment. A Terminal Management System needs a model to model container movements. Intelligent Truck Parking is similar in function to Dynamic Parking Guidance Systems, but addresses the particular needs of trucks (e.g. secured parking sites for high value cargo, information about departure times for lanes in parking areas so that trucks with the same planned departure time do not block each other. This system again is different from the other systems within the subcategory.

3.6 Safety and Emergency Systems

Safety and Emergency systems are subdivided into three categories, see Table 11. *Augmented awareness systems* are in-car systems that give information, warn and in some cases intervene in case of potentially dangerous situations. *eCall* initiates a call to an emergency centre in the event of an accident. *Inland waterway systems* registers vessels and their transport data at the beginning of a journey and updates the data during the trip.

Table 11: Subcategories and systems in the category "Safety and Emergency Systems".

Safety and Emergency Systems	
Subcategory	**ITS Applications**
Augmented awareness	Collision Warning System
	Cooperative Intersection Collision Avoidance System
	Drowsy Driver Warning System
	Lane Departure Warning System
	Night Vision System
	Vehicle-based Pedestrian Detection System
	Weather Information System
eCall	eCall
Inland waterway systems	River Calamity Abatement Support

3.6.1 Test case: eCall

Description of the system

The goal of eCall is to alarm emergency services after a vehicle crash as quickly as possible, and in case of severe accidents when involved persons are not able to call emergency, provide a link to ambulances automatically.

When a collision is detected by vehicle sensors, e.g. by airbag deployment or very strong deceleration, an eCall is initiated. The system establishes a GSM connection ("call") to a service/emergency centre; the position of the vehicle can be transmitted automatically if it is known from a GPS device (navigation). The operator in the service/emergency centre can deploy emergency services, ambulance and/or police to that location. It is foreseen that a voice link to the crashed vehicle is established, so the operator can contact the potentially injured passengers in the vehicle. This serves the purposes to obtain more information from these passengers if possible, to detect false alarms, to calm down the passengers or to detect a "non-response".

Effects of the system relevant for CO_2 emissions

No direct effects are expected from eCall. eCall is an application that becomes active in case of an accident. It does not change the way people travel or drive. Also no long term effects are expected from eCall. Accidents happen irregularly (both in place and in time) so eCall will not influence the way people travel or change the network.

Only an indirect effect is expected: because of eCall emergency services can be at the accident sooner, and maybe be able to help sooner/quicker because they know what happened and can send the right service (this depends on the exact implementation of eCall – whether information is sent together with the call or not). This means that eCall can have a local effect on infrastructure capacity (e.g. closing of lanes) and there is less congestion and delay because of accidents. However, such effects are very limited in number, times affected and also spatial relevance.

Path through Amitran methodology

The following describes the path through the methodology flowchart and indicates which model categories are needed to be able to calculate CO_2 emissions:

Demand model + Network (road)
↓ ↓
Microscopic flow model   Macroscopic flow model
↓ ↓
Trajectories → Link indicators
↓ ↓
Macroscopic emission model   Emission factors
↓
Emission data
↓
Scaling up

When it is possible to obtain real data about the amount of congestion/delay after an accident (with and without eCall) or make assumptions about this, emission factors can be used directly to translate these changes into CO_2 emissions.

One remark about this system is that it is a safety and comfort application, other effects are expected to be minor. First question should be whether one really wants to calculate CO_2 effects of eCall.

Input data

The input data needed for this case are:

- Accident data
    - The amount of congestion it causes
    - Time part of the road is closed
    - Number of lanes closed
- Network data: road network, OD data
- Data on the system: how does it work

Data are needed for the situation with and without eCall. The data can come from real-world, literature, or be based on assumptions.

Scaling up

For scaling up the direct method is preferred. Effects of eCall on CO_2 emissions are needed for different types of accidents (scenarios), and data on types of accidents on EU-27 level (or other level) are needed. This requires quite some research.

Scenarios

Accident characteristics are an important aspect to take into account for scenarios for eCall:

- Location (e.g. road type, number of lanes, distance from emergency service, link vs. junction)
- Type of accident (e.g. how many lanes are blocked)
- Severity (e.g. for how long are lanes blocked
- Traffic state (e.g. how many vehicles are affected by the accident)
- Country
- Etc.

3.6.2 Generalization to subcategories

eCall is a separate subcategory within the main category Safety and Emergency. Another subcategory is ***Augmented Awareness***. The systems in this subcategory have a direct influence on driver behaviour, which is different from eCall. This makes their assessment also different. The similarity is that the systems are active in case of an incident (e.g., collision, lane departure) and could maybe prevent accidents from happening and in that way also reduce the amount of congestion in an indirect way. Within the augmented awareness subcategory the Weather information system and Night vision system are a bit different from the others. They work continuously, while the other systems aim at avoiding accidents and dangerous situations and are therefore event-based. Therefore, for these two systems the assessment will be of a different nature.

The subcategory ***Inland waterway systems*** comprises only one system, River Calamity Abatement Support. This system is similar to eCall, but on the water instead of on the road.

4. Input data

As has been mentioned in the previous chapter, the assessment of ITS requires input data in order to enable the use of models. The exact input data depends on the system and the desired accuracy of the assessment. However, most assessments depend on a limited number of data types which will be outlined in section 4.1. Where or how this data usually can be acquired and who might have to be involved is described in section 4.2.

4.1 Data types

4.1.1 Transport supply data

All types of traffic models depend on data on the transport supply. The basic form of transport supply data is network data (roads, railway connections etc.). The level of detail depends on the specific requirements and can include capacities, travel times, slope, and traffic regulations either on a zone to zone level, or usually on link level.

Transport supply might also have to include some data on schedules of transport services (e.g. public transport timetables). Particularly for freight transport, schedule data is often not accessible to the modellers, so that simplified data for the available transport supply has to be used. Another option is to include the simulation of the transport supply in the model (e.g. the case in some logistics models).

4.1.2 Structural data and demand data

Particularly for transport demand models, structural data like data on the population, firms, economic data etc. is required. If the demand is not modelled, this kind of data can be replaced by demand data, commonly in the form of origin-destination-matrices.

4.1.3 System data

System assessment relies on a specific definition of the system under assessment. The system and its feedbacks with the environment have to be precisely described. This includes the way the system interacts with the environment and the descriptors reflecting this interaction. The relevant descriptors have to be incorporated in the used models. For instance, the dynamic traffic light system described in section 3.2.1 requires data on which signal program parameters are adapted in reaction to which traffic descriptors. If the control algorithm reacts to, for instance, queue length, waiting times, and the presence of vehicles/pedestrians, these parameters have to be an available output of the used traffic simulation.

4.1.4 Calibration data for base case

The used transport models have to be calibrated for a base scenario. This base scenario is used to derive the system's effect from a comparison with the application scenario. The calibration of the models can follow the common procedures, but should consider for the particular sensitivities needed for the system assessment. Since Amitran is focused on CO2 assessment, this requires a specialized calibration and validation, for example considering accurate accelerations. This has been described in ECOSTAND International Joint Report [9]. Data on changes in user behaviour due to the assessed system will be required as well (cf. 4.1.5). Possible calibration data can be, for instance, average trip distances for different traveller groups or count data for strategic screen lines in the network.

4.1.5 Data on changes in user behaviour

Crucial input data relate to the system effects. In order to reproduce the real world elasticities, these elasticities and the parameters affected have to be known. Deliverable 3.1 gives an overview of the parameters that might be affected by the respective systems. Data is needed to quantify these elasticities. This data is usually derived from either field operational tests or from surveys (revealed or stated preference).

4.1.6 Incident data

The effect of safety and emergency systems is closely related to the frequency and probability of incidents. Hence, data hereon is required (e.g. accident data with reference to road type).

4.2 Data sources

The mentioned data has either to be acquired from publicly available sources (statistics, commercial data providers), gathered for the assessment (e.g. stated preference surveys), taken from the literature (e.g. elasticities determined in past research), or it has to be provided by authorities or companies, which for example collected the data in a pilot study or Field Operational Test (FOT). With regard to FOTs, we can also refer to the FESTA Handbook [10]. Concerning driver behaviour, also driving simulator experiments can be done.

Quite often the data is not available to the extent desired. In this case assumptions have to be made. The documentation on the data sources, its accuracy, and on any assumptions is a crucial part of a transparent and reproducible assessment. It has to be stressed that the application of Amitran might presuppose the compilation of substantial data, e.g. by field operational tests. The feasibility of this type of preparatory research depends on the system and the application scenario on the one hand. Recently developed systems of a new kind, where no prior experience exists, will require more extensive research; also systems affecting more different parameters, e.g. not only driver behaviour, but also transport demand, will cause higher effort in the determination of user behaviour changes. On the other hand, of course, the available resources limit the options. A feasibility assessment has to be part of any project involving Amitran, as is already the case with projects related to ITS assessment.

In the context of Amitran, the party responsible for the use of Amitran has to make sure that all the required data is available in the level of detail needed for the model application. Usually some agreement with the party requiring the use of Amitran (the sponsor) will be needed on responsibilities for the provision of the data.

The Amitran Knowledge Base provides links to data sources not only relevant for scaling up, but also for other modelling steps (e.g. structural data).

5. Conclusion

For six test cases (six systems, one from each system category as defined in WP 3) the different steps in the Amitran methodology are described, including the choices that are being made and the 'path' that is followed through the methodology. From the test cases a generalization to all system categories is made, and the subcategorisation of systems is verified. It has been investigated whether an assessment for CO_2 effects could take place in the same way for all the systems within one (sub)category. If not, a subcategory is added for the Amitran methodology, such that our methodology offers a consistent approach for each of the (sub)categories. The new subcategorisation of systems is shown in Table 12 below. In bold italics the changes compared to the original typology are indicated: new subcategories are added or existing subcategories are split into two. In red italics the six test cases are indicated. The two categories "Navigation and traveller information" and "Traffic management" have been split into three categories, partly renamed for clarification and the assignment of sub-categories adjusted.

In Section 1.1 of this document the goals of the work and deliverable are described. The goals are reached in the following way:

- Verification of the typology of ITS: as described above, a new subcategorisation is proposed from an assessment point of view;
- Verification of the set-up of the methodology: there is no feedback coming out of Task 3.4 that requires changes to the methodology and/or framework;
- Bridging the gap between theory and practice: At this stage of the project the theoretical methodology and the developed framework required a check for major gaps in the draft, before the development is finished. This has been conducted by applying the methodology to the six (real world) test cases (as explained in Chapter 2) in a theoretical exercise as the in-depth validation with real data will take place in WP 6.
- Providing input to the validation on different types of cases: the results on applying the test cases can be used by WP 6 as an addition to the validation and verification work that takes place there;
- Providing examples for the online guidance tool and checklist: the results on applying the test cases can be used by WP 7 as content for the online guidance tool.

Table 12: Categories, subcategories and systems for assessment in groups (in bold italics the changes compared to the original typology).

Main category	Subcategory	System
Specialised navigation, information, and planning support	***Electric cars***[6]	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**	***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***
Traffic management and control	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
Demand and access management	***Electronic Fee Collection – toll***	*Electronic Toll Collection*
	Electronic Fee Collection – ticketing	Electronic Ticketing
	ITS Supported Measures	Restricted Traffic Zones Access Pricing Road Pricing

[6] In the future, when the electric car radius of action increases, the number of charging station increases and charging times decrease, electric cars probably do not need a separate subcategory any more.

Main category	Subcategory	System
Driver behaviour change and eco-driving	***Driving Assistance including cruise control & Driving Behaviour – recognition system***	Intelligent Speed Adaptation/Assistance Green Light Optimised Speed Advisory Adaptive Cruise Control Predictive Cruise Control Cooperative Adaptive Cruise Control *Autonomous Driving* Lane Change Assistance System Parking Assistance System Driving Behaviour Recognition System
	Driving Behaviour – tachograph	Digital Tachograph
	Railway Systems	Driverless Train Operation Energy Efficient Train Driving System
Logistics and fleet management	Public Transport Systems	Computer Aided Dispatch and Scheduling Operational Control System *Dynamic Schedule Synchronisation*
	Freight Transport Systems – management & planning	Electronic system for freight transport Fleet Management System Supply Chain Management System
	Freight Transport Systems – truck parking	Intelligent Truck Parking
	Freight Transport Systems – terminal	Terminal Management System
Safety and Emergency	***Augmented awareness – event-based***	Collision Warning System Cooperative Intersection Collision Avoidance System Drowsy Driver Warning System Lane Departure Warning System Vehicle-based Pedestrian Detection System
	Augmented awareness – continuous	Night Vision System Weather Information System
	eCall	*eCall*
	Inland waterway systems	River Calamity Abatement Support

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