METHODOLOGY AND FRAMEWORK ARCHITECTURE FOR THE EVALUATION OF EFFECTS OF ICT MEASURES ON CO_2 EMISSIONS

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ABSTRACT

Applications of Information and Communication Technologies (ICT) have been identified to have a significant contribution to reduce energy consumption and CO_2 emissions in the field of transport. The mechanisms by which ICT have an impact on CO_2 emissions can be very complex, and calculating this impact requires various models (e.g. traffic and emission models). Today, an integrated and harmonized modeling approach for the assessment of CO_2 emissions is not available, and knowledge on interactions between the required models is often missing. 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 CO_2 emissions. This paper describes two of the main outcomes of the project: the outline of the methodology to evaluate CO_2 effects of ICT measures and the framework architecture for this methodology.

Keywords: Intelligent Transport Systems, ICT measures, evaluation, methodology, CO_2 emissions, environment

1. INTRODUCTION

ICT measures can have a significant contribution to reduce energy consumption and CO_2 emissions in the field of transport. Today, an integrated and harmonized modeling approach for the assessment of CO_2 emissions is not available. 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 CO_2 emissions. This paper describes a methodology for the evaluation of the effects of ICT measures on CO_2 emissions and explains the framework architecture for this methodology (steps, models, needed interfaces and simulation environments). This methodology is developed within the 7th Framework EU project Amitran (Assessment Methodologies for ICT in multimodal transport from user behaviour to CO_2 reduction) [1]. All modes are included in Amitran with the exception of air transport and deep sea transport. All types of ITS applications are addressed (categorized into navigation and traveler information, traffic management and control, demand and access management, driver behaviour change and eco-driving, logistics and fleet management, safety and emergency systems). One of the major goals of Amitran is to create a methodology not only for ITS applications available now, but for any ITS application that might exist in the future, and therefore the methodology is designed in such a way that future inclusion of new types of ITS applications is possible. Changes in the infrastructure network, public transport scheduling and freight transport scheduling as a result of ITS applications (usually these changes occur on the long term) are not included. The focus of Amitran is on the assessment of CO_2 effects, and a "well-to-wheel" approach is used; this means that not only direct CO_2 emissions are taken into account, but also the additional CO_2 emissions needed for energy production. The geographical scope for Amitran is the EU-27 countries, however in principle the methodology can be applied on all scales. The full description of the Amitran methodology and framework architecture can be found in Deliverable 4.1 of Amitran [2].

2. DEFINITION OF THE METHODOLOGY

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 categorization, factors and parameters influenced by ITS, transport system, parameters relevant for CO_2 emissions and scaling up.

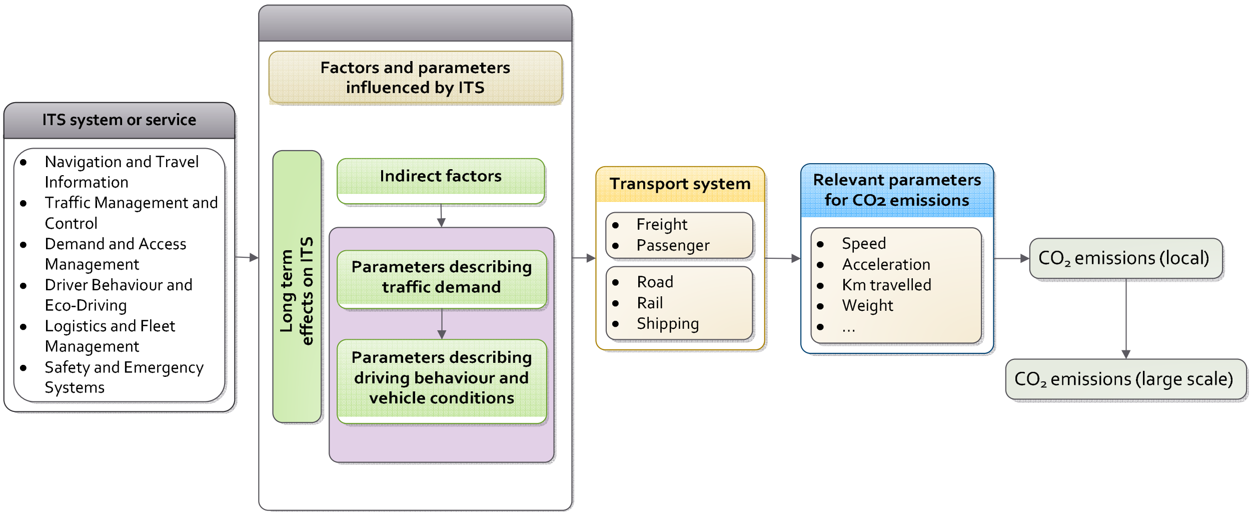

Figure 1. The chain from ITS systems to CO_2 emissions

Starting from an ITS system, the system can have a direct and/or indirect influence on driver or traveler behaviour and on vehicle conditions. For example, an ITS which bans heavy duty vehicles (HDV) from a certain area (e.g. city centre) will reduce the number of HDVs as a direct effect. However, the number of light duty vehicles might increase as an indirect effect. These direct and in direct influences can be described by factors and parameters which are defined in deliverable D3.1 of Amitran [3]. 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. The mechanisms can be distinguished into four groups as follows:

1. *Parameters describing traffic demand*, such as trip generation and departure time choice (direct effects);
2. *Parameters describing driving behaviour and vehicle conditions*, such as speed and headway (direct effects);
3. *Indirect factors*, when an ITS system influences traffic/transport indirectly (e.g. infrastructure capacity can be influenced by Adaptive Cruise Control and that in turn influences demand); and
4. *Long term effects of ITS*, such as changes in the public transport schedule.

Together these 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, kilometers 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.

Besides output on CO_2 emissions, also fuel consumption can be acquired as an output of energy efficiency, since there is a clear relationship between fuel consumption and CO_2

emissions. Other emission types like NOx and PM10 can often be received as output as well, but that depends on the possibilities of the models that are used.

3. GENERAL OVERVIEW FRAMEWORK ARCHITECTURE

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, as explained in the previous section. 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. A general overview of the framework architecture is given in Figure 2.

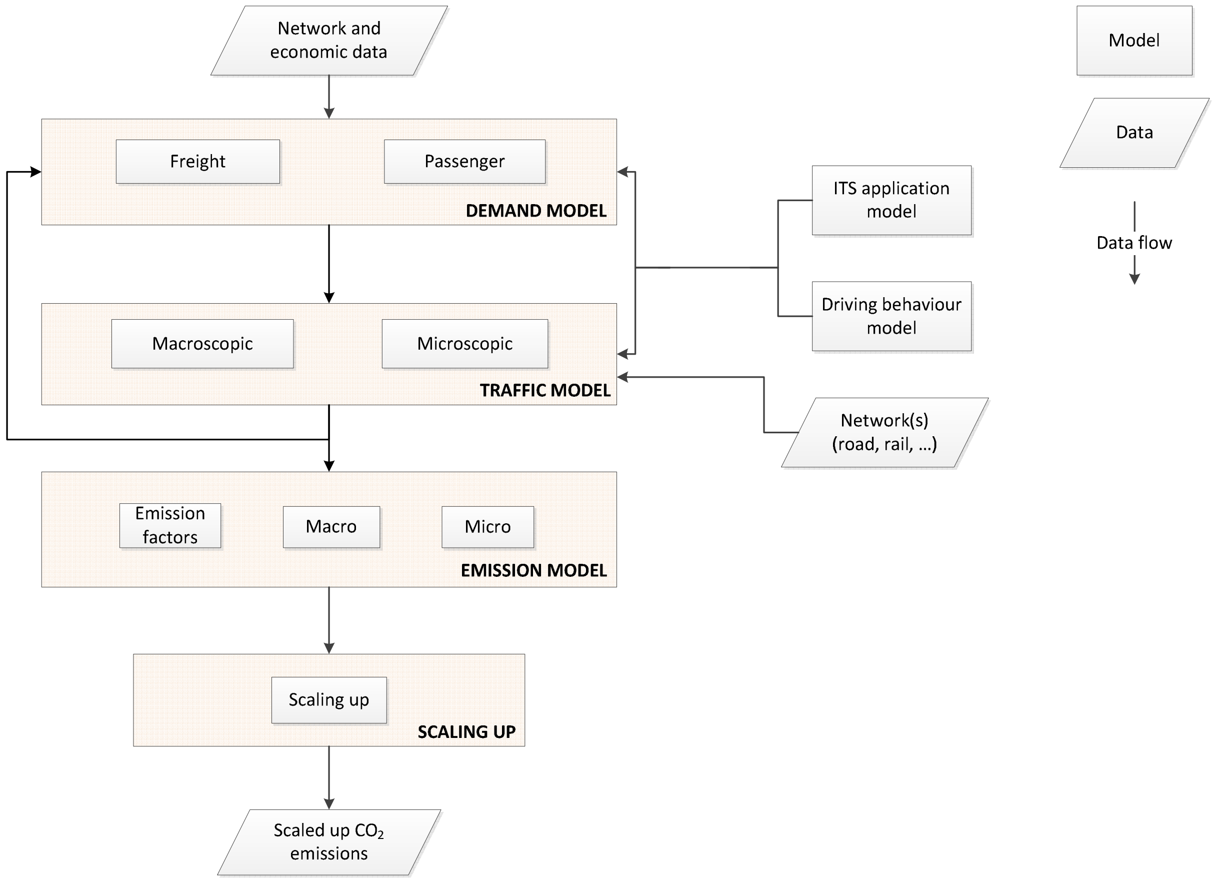

Figure 2. General overview Amitran framework architecture

The framework is divided into four main parts: demand modeling, traffic modeling, emission modeling and scaling up. First a *demand model* is used to create the traffic. A distinction is made between freight and passenger traffic due to the differing demand models creating the respective parts of the total traffic. The input into the passenger demand model are socio-economic data relating to the area used for the investigations; for the freight part the input consists of the locations of production, consumption and intermediate locations in the freight flow, as well as general economic data. For both models (as well as for the traffic model) the network on which the traffic takes place is input; its most important parameters are – apart from the graph structure of the network itself – the capacities, volume-speed-relationships for the network links, and nodes. Within the freight demand model the modal split model is distinguished (not shown in the figure). The relative costs and time of the different modes are influencing the choice for the (combination of) modes. Output of the modal split model is the (changed) modal split in terms of tonnes by mode by commodity group and OD.

The *traffic model* creates the traffic flow and provides thus the data for the emission model. The term ‘traffic model’ is sometimes used for data describing a specific situation, e.g. as ‘traffic model for city X’. In contrast to that we refer here with ‘traffic model’ to algorithms that can transfer the demand to link attributes or trajectories. For passengers the traffic model often incorporates the demand model. The output of the traffic modeling consists of the amount of traffic (vehicle mileage), information on the weight/occupancy of vehicles, the characteristics of traffic (e.g. average speed per link), and in case of a detailed microscopic approach data on the individual vehicles (e.g. acceleration profiles).

These data feed into the *emission modeling* part. The types of emission models to be employed depend on the type of traffic data used: for aggregate traffic data emission factors or macroscopic emission models are suitable while microscopic traffic models feed into detailed microscopic emission models. These emission models generate the amount of emission for the application case (area size and time) under investigation.

Scaling up of CO_2 emissions (to country level or EU-27 level for example) is done within the framework, either within the models, or after the modelling, using statistics. The scaling up process is described in a detailed way in [4], and is therefore not described in this paper.

4. CONNECTION BETWEEN PARAMETERS INFLUENCED BY ITS AND THE FRAMEWORK ARCHITECTURE

As stated in Section 2 of this paper, the Amitran approach makes use of the mechanisms by which ITS exert their influence. These mechanisms (partly) determine how the assessment should be carried out and what types of models should be used. Figure 3 shows the connection between parameters influenced by ITS (the first and second mechanism as listed in Section 2) and the framework architecture.

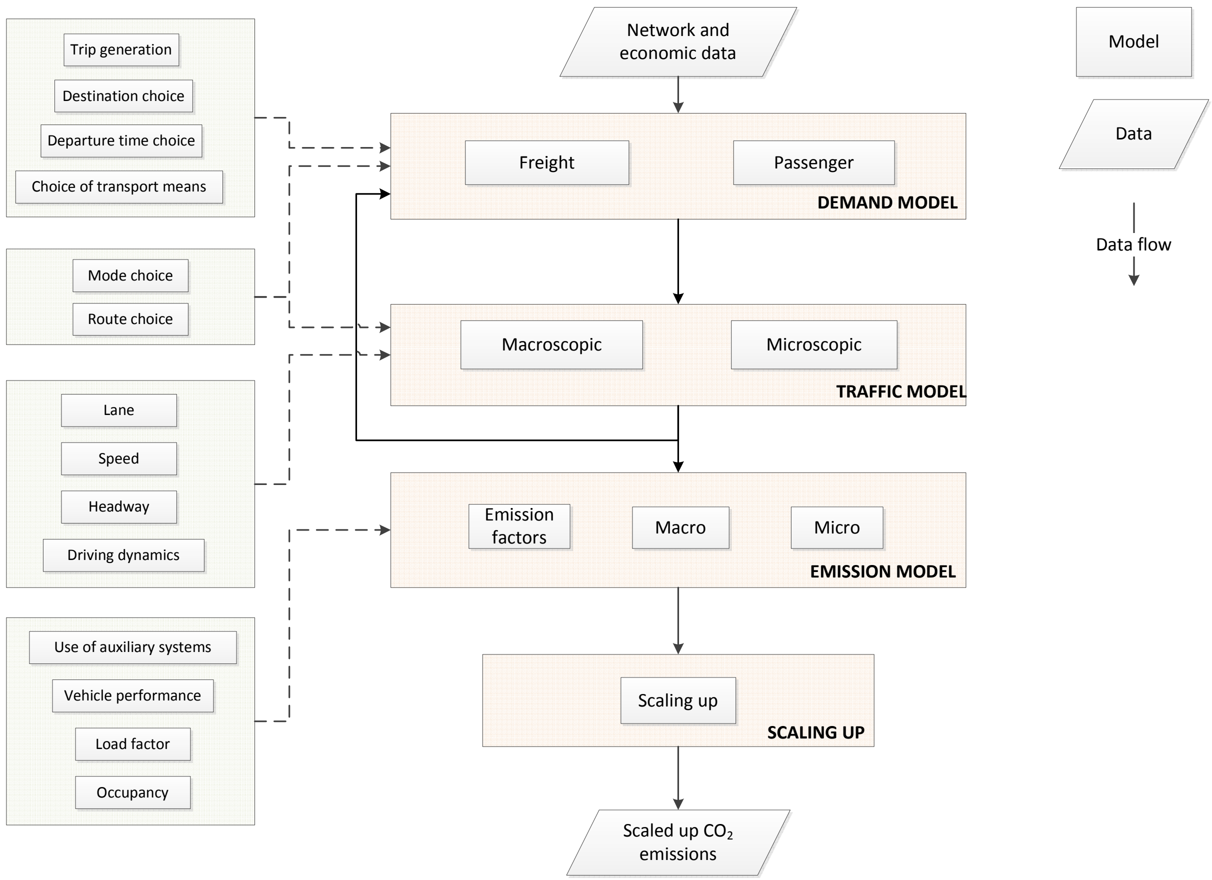

Figure 3. Connection between parameters influenced by ITS (on the left) and framework architecture

First there is a group of parameters describing demand, and when an ITS system influences these parameters, changes in the demand modelling need to be made. For passengers the parameters trip generation (number of trips made from a certain location), destination choice and departure time choice determine the number of trips for each origin destination pair per mode per time unit, and together they describe demand. For freight transport, demand describes the amount of goods per unit time from a certain origin to a certain destination. In the Amitran context it is assumed that location of production, distribution centres and consumption (i.e. the location of customers) and the demand for goods generated is unchanged (as first order effect) by the ITS system in consideration and therefore can be regarded as input. Choice of transport means (the vehicle (type) that is chosen within a mode) is a refinement of the mode choice and plays a role in freight transport more than passenger transport. Route choice and mode choice are parameters that connect to both the demand model and the traffic model. It depends on the exact implementation of the ITS system (e.g. whether route choice and mode choice are influenced pre-trip or on-trip) for which model(s) they are relevant. The third group of parameters are about driving behaviour. They cover ITS systems that influence the direct driving behaviour for all modes, i.e. the operation of a car, train or vessel, e.g. by addressing speed choice by taking over parts of the driving task like

ACC does for cars or trucks. For road traffic, such systems can optimally be treated by microscopic simulation that handles individual vehicles. The fourth group of parameters are external parameters that are input for the emission modelling. The auxiliary systems (e.g. air conditioners, heating systems) use energy from the vehicle to operate; therefore they influence the emissions factor of the vehicle (through the energy consumption). Their energy need is directly linked to the related CO_2 emission. The occupancy of a vehicle (number of passengers) determines the total weight of a vehicle, which in turn influences the emissions. The same holds for the load factor of a vehicle, ship or train. The higher the occupancy or load factor of the vehicle, the higher the emissions are.

5. FRAMEWORK ARCHITECTURE IN MORE DETAIL

An elaborated picture of the framework architecture is given in Figure 4. The four main parts of Figure 2 are still visible, but more details are added, especially the information flows between the model parts. An important addition to the more general picture are the data boxes ‘ITS application model’ and ‘Driving behaviour model’. This is where the influence of the ITS system (compared to the situation without the system) and the driving behaviour form input to the models. Another addition in this more detailed picture is the information flow between the traffic model and the emission model. A microscopic traffic flow model uses driving behaviour, including speed choice, acceleration choice, etc. to generate the traffic flows on a network with the individual vehicles’ movements. While microscopic models reproduce the traffic streams in a network by generating the movements of individual vehicles, macroscopic models create flows of vehicles by using a macroscopic approach, like a capacity restraint approach. The output of the traffic model feeds into the emission model. Depending on the complexity and the traffic model used, the emission model can vary from a simple approach over a macroscopic model to a fine grained microscopic model. The data flow consists of the amount of traffic (vehicle mileage), information about the weight/occupancy of vehicles, the characteristics of traffic (e.g. average speed per link), and in case of a detailed microscopic approach data about individual vehicles (e.g. acceleration profiles). For the emission calculation, different models can be used, depending on the availability of data, usability (size of application) and availability of modelling approach. These emission models generate the amount of emission for the application case (area size and time) under investigation.

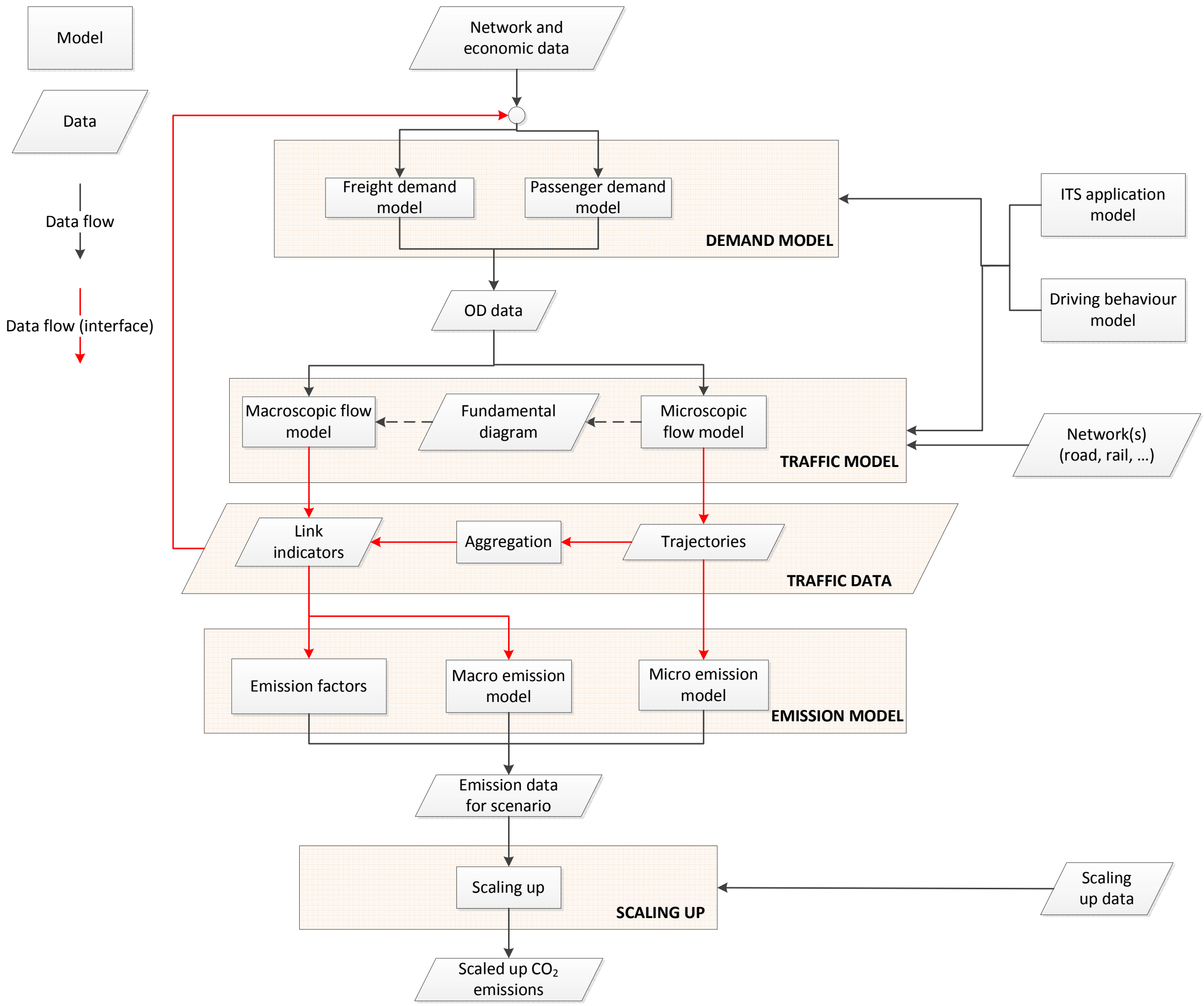

Figure 4. Detailed picture Amitran framework architecture

5.1 Second order effects

When an ITS system is researched that has an effect on demand, it is possible that there is a second order effect. For example, if there is a change in modal split (more people use public transport instead of the car) or departure time (less traffic in peak hours), this has an influence on throughput: there will be less congestion and a better flow of road traffic. This might induce extra traffic demand, such as people changing from train to car when they notice there is less congestion. This can be taken into account by specific models for such effects. The information flow comes from the output of the flow models and then feeds into the demand boxes (arrow on the left side in Figure 4).

5.2 Model requirements and interfaces

In the Amitran project model requirements, interface requirements and interfaces between the models are being developed. The model requirements give for each model type (e.g. microscopic emission model) a technical description, inputs and outputs. Since Amitran does not develop new models the requirements are on a functional level, and not on a software level. Generally speaking the output of a model must contain the information the "follow-up" model requires for processing the next step. For example a microscopic emission model which expects speed patterns of individual vehicles requires a traffic model that can supply this; which means a microscopic traffic simulation model. On the other hand, a more aggregated model like a macroscopic emission model requiring average speeds per network link can be fed by a microscopic traffic model; the average speeds can be determined from the individual vehicles' speed patterns. While such an aggregation is always possible, a dis-aggregation, like determining individual speeds or even speed distributions from an average speed per link, requires additional (modelling) assumptions that generally reduce transparency and trust in the overall approach. For the interaction between models interfaces will be developed by Amitran. The interface describes how the output of one model can be translated into input for another model. The interfaces that will be developed by the Amitran project are indicated by the red arrows in Figure 4: interfaces between microscopic and macroscopic traffic models, from traffic models to emission models and from traffic model output to demand modelling will certainly be developed.

6. OUTLOOK

Based on the methodology and framework architecture as described in this paper, at the moment the model requirements are being detailed and the interfaces are being defined. The interfaces will be made publicly available in 2014. To explain the methodology and help users who want to do an assessment using Amitran, a handbook and checklist will be developed. These products will also become publicly available in 2014.

7. REFERENCES

[1] http://www.amitran.eu/

[2] *Amitran D4.1: Requirements and design of the methodology*, version 9 (draft version), November 2012.

[3] *Amitran D3.1: Methodology for classification of ITS*, version 11, July 2013.

[4] Dick Mans, Eline Jonkers, Ioannis Giannelos, Dorin Palanciuc, *Scaling up methodology for CO_2 emissions of ICT applications in traffic and transport in Europe*, 9th ITS European Congress, Dublin, 4-7 June 2013.