Scaling up methodology for CO_2 emissions of ICT applications in traffic and transport in Europe

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Abstract

The Amitran project aims to define a reference methodology for evaluating the effects of ICT measures in traffic and transport on energy efficiency and consequently CO_2 emissions. This methodology can be used as a reference by future projects and will address different modes for both passenger and freight transport through a comprehensive well-to-wheel approach. Scaling up is an important part of this methodology. Starting from the identification of user behaviours and transport characteristics affected by Intelligent Transport Systems (ITS) and their correlation to parameters affecting CO_2 emissions, the development of a generic scaling up methodology aims at the translation of CO_2 emission effects from a local level to a larger (e.g. European) level. For scaling up two methods are distinguished: a direct method using statistics and one using a macroscopic multimodal traffic model. The selection of the used method depends on the type of expected effects and the availability of relevant models. In the course of the Amitran project a knowledge base will be developed to provide guidance to the Amitran users to scale up their results. The knowledge base will also provide examples of scaling up for different ITS applications and links to relevant data.

KEYWORDS: Scaling up methodology, ITS, CO2 emissions, knowledge base.

Introduction

The application of ITS is seen as very promising to help reduce the negative consequences of transport. In current European transport policies and research frameworks, emphasis is given to the importance of considering the environmental impacts of transport and the promotion measures which can help reduce these negative impacts. A growing number of 'green' versions of ITS applications and services are in fact now being developed [1]. However, the mechanisms which have an impact on energy efficiency and CO_2 emissions are very complex, while a complete methodology and tool set to determine this impact on EU level, taking into account changes in travel behaviour, is missing. For a proper steering of the ITS (including eFreight) developments and applications, a robust and reliable environmental evaluation framework is crucial.

The aim of the Amitran project is to develop a framework for the evaluation of the effects of ITS applications on energy efficiency and consequently on CO_2 emissions. Ambition of the project is to define a reference methodology that can be applied in future projects that assess the impacts on CO_2 emissions the deployment of various ITS applications can induce. The scope of Amitran includes all transport modes and existing types of ITS applications, except for applications related to air and deep sea transport. Additionally, the methodology is designed in such a way that future inclusion of new types of ITS applications is possible.

The calculation of CO_2 emissions using the Amitran framework includes a number of steps. First step is the identification of ITS systems and services that influence parameters of user behaviour or transport characteristics, and this step is followed by the correlation of those to parameters affecting CO_2 emission. Then, a reference CO_2 assessment methodology for the various ITS applications is set up, based on the design of open interfaces for models and simulation tools. The last step in the Amitran framework is the scaling up of the CO_2 emissions: the extrapolation of impacts on CO_2 emissions from local level to a higher level, for example country or EU-27 level.

Two methods of scaling up are proposed in the Amitran methodology, as shown in Figure 1 and explained in following sections. The first method is a direct method, using a knowledge base with statistical information. The second method is performed through modeling using a macroscopic multimodal traffic model on EU-27 level. The choice of scaling up method is based, among others, on the availability of models and the type of effects expected.

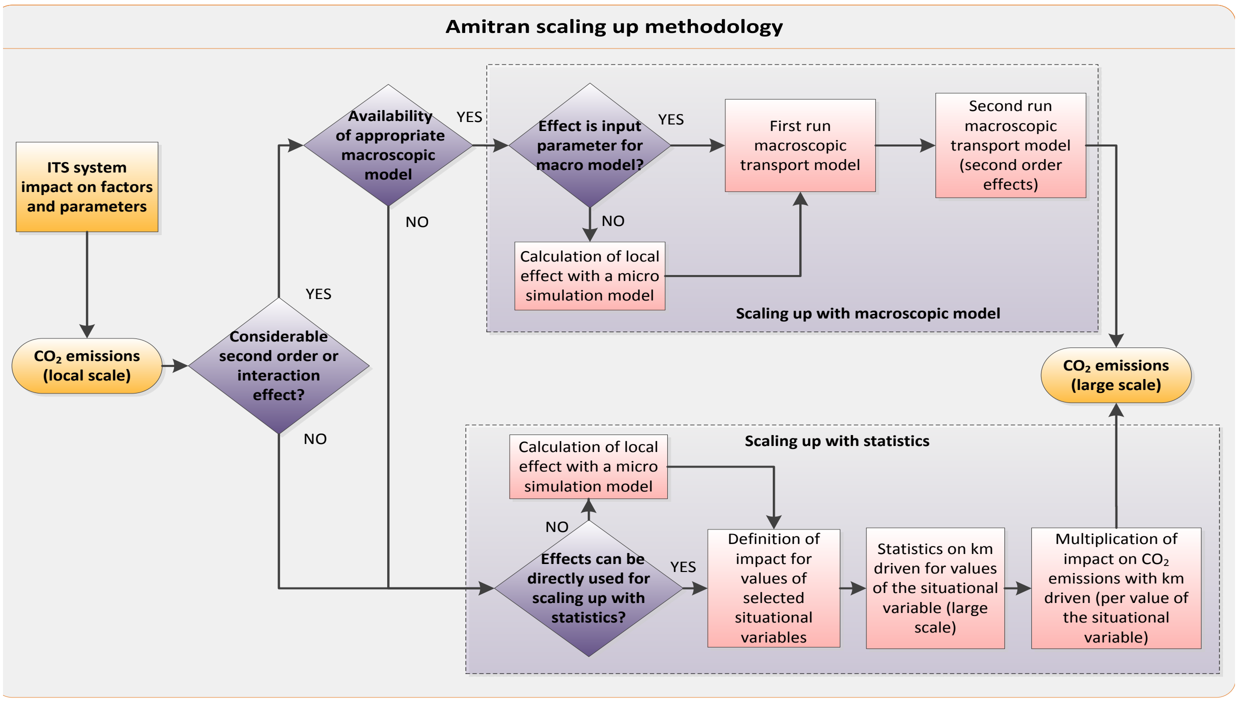

Figure 1: Amitran methodology flowchart

Scaling up using statistics

The scaling up process using statistics initiates from the impacts on CO_2 emissions at a local level as distinguished for different situations (such as traffic state, vehicle type, etc.). The impacts at a local level can for example come from an experiment, literature, a micro simulation study or a combination of these approaches. In case it is not possible to directly use the local CO_2 effects of ITS to scale up with the use of appropriate statistical datasets (i.e. reduced acceleration and deceleration of vehicles in congestion), then the use of a microscopic model, such as [4], is necessary to transpose this impact to a more appropriate format for scaling up (i.e. 10% reduction of CO_2 emissions on congested highways).

The definition of situations depends on the system characteristics, the situational variables that are expected to have the largest impact (e.g. a night vision system will only be active during driving in the dark), the possibility of measuring the different situations and the model capabilities. Data for the same situations is needed on the large scale level that is targeted. Then, the impact on CO_2 emissions on a local scale are scaled up using statistical data (for example on kilometres driven for the relevant modes) under the specific situations.

Scaling up using statistics is applicable when interaction and second order effects (i.e. latent demand induced by the improvement of the service level, caused by an ITS) can be expected to be insignificant, or when there is a clear effect at certain traffic situations for which data on higher level are available, or even at the mere event that no appropriate macroscopic model is available to perform the model-based methodology. A drawback of this method is that data sets need to be available for all countries. At present there is very limited measurement data for some countries in Europe while a (software) tool for this approach does not exist yet.

Scaling up using a macroscopic multimodal traffic model

The network of a macroscopic multimodal traffic model determines the level on which the results are calculated. Ideally the model is available on country or EU level. Scaling up using such a model can be done in two different ways:

1. The calculation of the impact is done with a model other than the macroscopic traffic model. The local effects of the ITS system are in this case determined (e.g. via a microscopic simulation tool). These effects can be used as input for the macroscopic model on country/EU level. One run is performed for deriving the direct effect to a larger scale. Optionally, the economic effect can be calculated with an appropriate model and a second run of the macroscopic model is performed so that the second order effect is also accounted for.

2. The calculation of the impact is performed directly with a macroscopic traffic model. In this case, should the model be at the required level (country/EU), the direct effect of the system is calculated. This can be done performing a run of the macroscopic model. Optionally,

same as for case 1, the economic effect can be calculated with an appropriate model. Then a second run is performed with the macroscopic model to account for the second order effect. A limitation to this approach is that microscopic effects of ITS cannot be taken into account, e.g. changes in driver behaviour. Therefore it can only be used to determine the effects of ITS that mainly affect macroscopic mechanisms in the network, such as mode or route change.

The two alternatives are very much alike. In the first case, the macroscopic model is used purely for scaling up and possibly for calculating the second order effects, while the impacts on CO_2 emissions are calculated by another model. In the second case, the macroscopic model is used for calculating the impact on CO_2 emissions as well as for scaling up. Scaling up using a macroscopic model is a good method to apply when second order effects are expected and/or when the effects of the ITS system can be used directly as an input parameter for the macroscopic model. Also, this method can be used only if such a large-scale model is available. An example of such a model is the model TransTools [5]. Being a more elaborate method than scaling up using statistics, it allows taking into account specific circumstantial differences especially if there are interaction effects. A downside of scaling up with a macroscopic traffic model is that urban roads are usually not part of the network on such a large scale, and that it requires more effort than scaling up using statistics.

Limitations of scaling up

The methods described above explain how scaling up can be applied theoretically. In practice, scaling up is a big challenge. It is important to consider the goal one wants to achieve. Scaling up is not a goal on itself, but is rather a means to answer a certain question or to achieve a certain result. This section discusses when scaling up makes sense and what are the limitations to its application.

The general idea behind the scaling up methodology is that the results of the use of a system in a certain area are also expected to be valid in comparable situations elsewhere. Therefore applying the scaling up methodology makes sense when the system for which you know the results on a small scale, are (likely to be) valid in other regions as well, considering the case that the system is implemented there in the same degree. Therefore, the network and the type of system in consideration are very important to determine for which regions/cities the effect will be comparable. For example, a driver assistance system that gives a warning for road works, will normally have a similar impact for road works on similar roads. For motorways and rural roads the extrapolation of the impacts of a system to a larger scale is usually possible. For systems that are active in urban environments it can be more difficult to extrapolate results, because cities have different characteristics and are often not comparable (e.g. the impacts the same system might have in a compact old city with narrow roads such as Amsterdam and a spacious city like Rotterdam are usually not comparable). Also the type of existing ITS in the city may be very different and impact the results of introducing new ITS. Thus, in case no further information on city characteristics and/or no results for comparable cities are available, then the extrapolation of results might not (always) be reliable.

Scaling up for different types of systems

The Amitran project takes into account ITS in various fields: systems related to passenger and freight transport used in road, rail, and inland waterway traffic. To make sure that all relevant systems are covered, an existing categorisation of ITS systems is taken as a starting point and the systems belonging to each category are identified. The categories of systems (including some examples) are the following:

- Navigation and travel information (navigation systems, traveler information systems, planning support systems, inland waterway information systems)
- Traffic management and control (signal control, junction control, enforcement systems, parking guidance)
- Demand and access management (road pricing, electronic toll collection, restricted traffic zones)
- Driver behaviour and eco-driving systems (driver assistance systems such as ACC, CACC, intelligent speed adaptation, lane change assistance, railway systems such as driverless train operation)
- Logistics and fleet management (public transport systems such as dynamic schedule synchronization, freight transport systems such as fleet management system, supply chain management system)
- Safety and emergency systems (lane departure warning, eCall, night vision system, collision warning system)

This categorization comes from the coordination and support action ECOSTAND from the 7th Framework Programme of the European Commission. In ECOSTAND this categorization was discussed and agreed upon on international level (Europe, Japan and the US). This categorization can be found in Deliverable 2.1 of ECOSTAND [6]. Similar to Amitran ECOSTAND is focused on defining a common methodology to estimate CO_2 emissions influenced by ITS. Therefore, this categorization was followed also in Amitran.

With regard to the type of functions one wants to scale up for, the following can be said:

- Navigation and travel information: the operation of navigation and traveller information systems depends very much on the (alternative) options a traveller has. In a densely populated urban area there are usually more travel options than in more rural areas, as in densely populated areas there are usually more route alternatives than in less densely populated areas. If there is knowledge on the level and amount of travel options (for public transport and/or car), the scaling up process can be made more reliable.

- Traffic management and control: these systems are usually designed for and applicable in a certain situation. Depending on how specific the implementation of the system is and the network characteristics (number of controlled intersections etc.), the effects of the system can be used for scaling up.
- Demand and access management: for demand and access management applications the transferability of impacts to other regions is not so straightforward. The exact implementation of such a system often depends on the type of problem that has to be solved and the type of network it has been developed for. Also user behavior for these applications may differ significantly between countries. Scaling up to EU level is likely not to be reliable for these types of systems. However scaling up within a country could be done since there are more similarities in the implementation of the overall system.
- Driver behaviour and eco-driving systems: these systems are usually applicable in all kinds of situations and they work continuously. When local results are available on the effects of a specific system for different road types, traffic situations (amount of traffic), and possible other situations, scaling up is possible and pretty straightforward. However, also for these systems one should take into account that driving behaviour differs for different countries.
- Logistics and fleet management: the implementations of such systems are very much depending on the specific characteristics of a company, such as the number of trucks, shipment sizes, number of clients, use of hubs and distribution centres. In order to get useful results that can be used for scaling up, a reliable sample size for different classes of companies should be obtained. Then for the larger scale also the amount of companies in a certain class should be known to be able to scale up the impacts of the systems in a reliable manner.
- Safety and emergency systems: just as for driver behaviour and eco-driving systems, these types of systems are usually applicable in all kinds of situations, and scaling up is possible and pretty straightforward, though they might be dependent of the current traffic safety level of a country (infrastructure types, more dangerous behaviour etc.).

Specifying scaling up for different types of ITS makes clear that it is difficult to say something general about scaling up. There is no ‘cookbook’ for scaling up and the method needs to be adjusted to each specific situation. Issues that possibly need to be taken into account (besides the ones already mentioned) are interaction between users and non-users, nonlinearity in penetration rates and cultural differences (differences in driving styles between countries). In Amitran not all those issues are handled at once, but contributions are made to take the methodology evolution to a next step by providing a knowledge base at the end of the project, as described in the following section.

Scaling up knowledge base

A knowledge base for scaling up is being developed by the Amitran project. This knowledge base is meant to provide guidance in scaling up, as well as reference (examples). The knowledge base is structured as follows:

- General information about scaling up
- Detailed information about scaling up for specific user cases – the set of specific use-cases shall be updated and extended as the methodology is being employed in real-life usage cases
- Examples of scaling up – for different transport modes, for passenger and freight transport, and for scaling up to different levels.
- Links to data needed for scaling up – at European and national level. Databases containing statistical data are being developed and maintained across the entire community. Some of the data contained in these databases and repositories can be used for scaling up. Direct inclusion of this data into the knowledge base would ease access for the users of the assessment framework, but would pose significant challenges in keeping the local data copy consistent with the original, therefore we've chosen to include links to existing databases.

There are many types of ITS being deployed at the moment, and new types are being developed and will be deployed in the (near) future. Their application and concrete implementation details are so diverse, that it is not only difficult, but also not recommended to have the knowledge base structure "set in stone". A more dynamic solution was employed, as there are two major driving forces that dictate the structure and content of the scaling up knowledge base: a) the users and b) the authors of the Amitran assessment methodology

In order to have them both acting freely on the knowledge and incrementally shape it, a wiki framework is used to host the knowledge base. The wiki can be browsed freely on the Internet. However, only registered and properly authenticated users are allowed to contribute. During the Amitran project the structure and content is being continuously reviewed and amended by the Amitran team. The continuous stream of changes and additions is being automatically tracked and properly displayed by the technologies used in the concrete implementation of the knowledge base.

The content of the knowledge base is structured in articles, covering one topic, or one aspect of a larger topic. There is a primary tree structure to be defined, hosting all articles. Based on the methodology needs, cross references between articles will be used, so that at maturity, the knowledge base will resemble a graph of articles, with links to external data sources. The knowledge base is meant to evolve, driven by both the ITS body of knowledge as well as concrete usage scenarios for the Amitran methodology. What the Amitran project aims at is that users of the methodology can confirm and, if possible, improve the scaling up methods, based on their concrete experience. A method to make users easily return the benefits and make their assessment scenario available to future users is being researched into.

Outlook

The general outline of the scaling up methodology has been developed as described in this paper. Next step in the course of the Amitran project is the collection of links to data required for scaling up, both at a European level and at national level. Inconsistencies in definitions, level of detail and availability of the required data for the various EU member states are expected. Therefore a classification is made between the necessary and optimal data. Further effort will be steered towards overcoming the aforementioned inconsistencies, either through educated assumptions or extrapolation from areas where similar conditions are met. At the same time the knowledge base will be developed and implemented. Finally, the methodology will be validated with selected use cases in an attempt to cover a variety of different circumstances, at which scaling up of impacts is required.

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