VALIDATION SCHEME FOR TRAFFIC SIMULATION TO ESTIMATE ENVIRONMENTAL IMPACTS IN 'ENERGY-ITS PROJECT'

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ABSTRACT

This paper introduces the validation scheme for traffic simulation to estimate the CO2 emission from automobiles. In the paper, rational association of traffic simulation and CO2 emission model is discussed at first. Following to the discussion on the reference models of CO2 reduction measurement, the verification and the validation procedures focusing on individual vehicle trajectories will be summarized. Those activities are part of the project 'Development of Energy-saving ITS Technology' which is organized by NEDO (New Energy and technology Development Organization) in Japan.

INTRODUCTION

From FY2008, 'Development of Energy-saving ITS Technology' Project organized by NEDO Japan was launched. One of the major research topics for which the authors are responsible in Energy ITS Project is to establish the rational procedure to estimate the CO2 emission from automobiles.

Figure 1 shows the six research directories consisting of our activities to establish the estimation method for CO2 emission. Developing traffic simulation and CO2 emission models are the most significant technical issues.

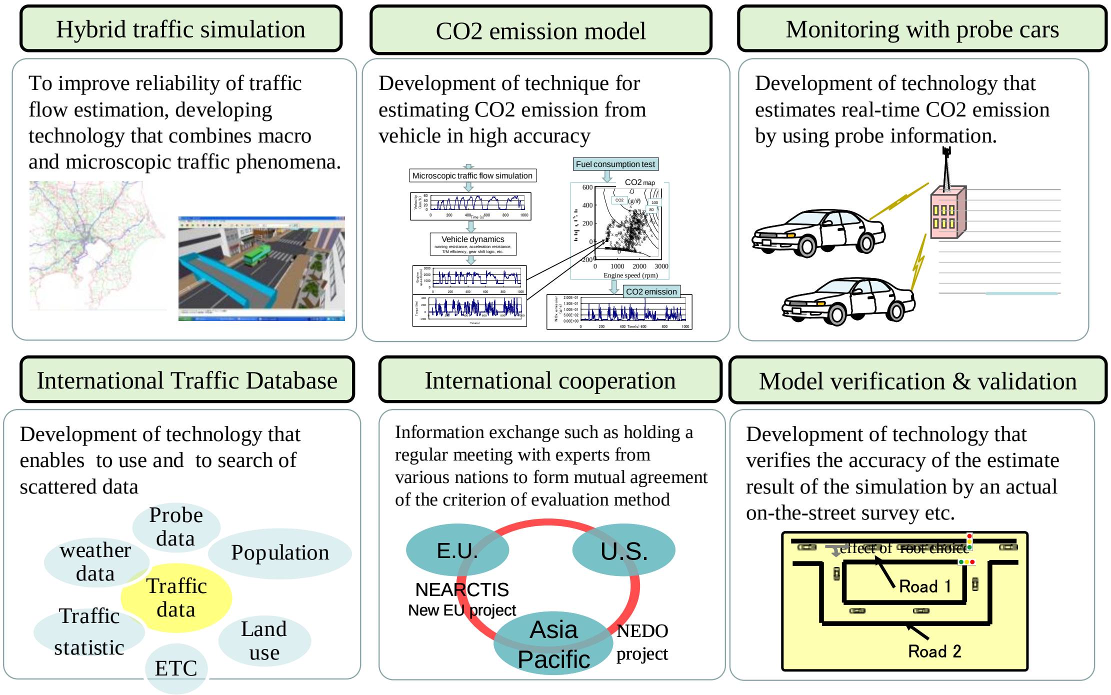

Figure 1: Research directories to establish the estimation method in Energy-ITS project

In this paper, rational association of traffic simulation (TS) and CO2 emission model (EM) is discussed at first. Following to the discussion on the reference models of CO2 reduction measurement, the verification and the validation procedures focusing on individual vehicle trajectories will be summarized.

THE RATIONAL ASSOCIATION OF TS AND EM

Sort of the Granularity of Vehicle Trajectory in TS

There are dozens of TS which are now used in practical study. Since the energy-saving measurement varies from the microscopic one that works on instantaneous driver's behavior, such as 'eco-driving', to the macroscopic one over the driver's trip behavior, such as 'eco-route guidance' or 'inter-modal shift', TS has to deal with individual vehicle movement in the city size or the region size area, if we are going to consider those measurement at once. Let us here classify those traffic simulation models in terms of the granularity of vehicle trajectory as shown in Figure 2.

As for 'Link-wised linear', a vehicle runs at the average travel speed which depends on the flow-density relationship of the current link. The position of the vehicle is identical only at each end of the link. 'State-wised linear' means that a vehicle stops and runs at the constant speed determined by speed-density relationship of the current link. The position of the vehicle is approximately identical at each position on the link. 'Fine grained' shows the most precise vehicle movement. A vehicle stops and runs according to some car following model which updates the acceleration of the vehicle with sufficiently short interval. The position of the vehicle is identical at each position on the link. The first two types are called piecewise linear (PWL) trajectories and the last one can be regarded as 'continuum' trajectory.

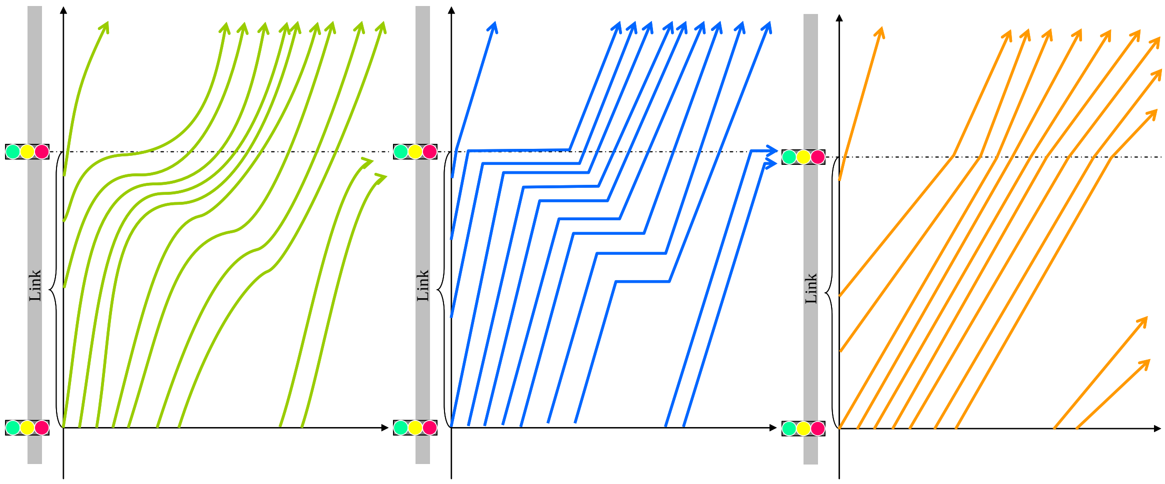

Figure 2: ‘Fine grained (left)’, ‘state-wised linear (center)’ and ‘link-wised linear (right)’ trajectories in TS

Sort of EM

EM can be classified as well in terms of granularity of vehicle movement. The simplest but most popular EM is a ‘trip motive’ type which uses the average travel speed of a vehicle trip. In this type, the macroscopic function to calculate the exhaust volume per unit distance is provided according to the average speeds of ‘typical’ observed trips.

Another EM which is popular for mechanical engineers is an ‘instant motive’ type which calculates energy consumption per short time period with the power and the torque that a engine produces. By combining the power transmission model, this type of EM provides the microscopic function between the instant CO2 emission and the vehicle running speed.

There are medium grained EMs between the macroscopic and the microscopic ones, so-called mesoscopic type. This type calculates the amount of emission for a short travel, e.g. from one stop to the next stop, according to the proportion of vehicle traveling mode, such as idling, accelerating, decelerating and cruising.

Association of TS and EM Mediated with Piecewise Linear Trajectory

As we mentioned, the energy-saving ITS measurements would work to improve driving behavior in microscopic scale, while some others would induce trip behavior changes in macroscopic scale. As for the microscopic level, people might expect TS to produce fine grained trajectories to feed the microscopic EM which accumulates instant emission depending vehicle's speed and acceleration. It is however suspicious from the viewpoint of rational use of TS in regional size network, since many of the microscopic TS do not guarantee the validity of vehicle movement in acceleration level for a wide area. It is recommended that the output trajectories from microscopic simulation will be simplified to state-wised or link-wise linear trajectories to feed CO2 emission models. Table 1 shows the rational association of TS and EM for a wide area study.

Table 1: Rational association of traffic simulation and CO_2 emission model

		Modeling level of CO2 emission model		
		Macroscopic (trip motives)	**Mesoscopic** (PWL)	**Microscopic** (fine grained)
Granularity of vehicle trajectory in traffic simulation	**Link-wise linear**	✔		
	State-wise linear	✔	✔	
	Fine grained	✔	✔	**???** (pessimistic about the region wide study)

THE REFERENCE MODELS FOR MODEL DEPLOYMENT

In this project, we will NOT intend to develop or specify models nor software to be used for CO_2 evaluation, BUT may employ various models as long as the models and software are well verified and validated. In this sense, we have proposed the reference models for the following stages; 1) modeling, 2) verification & validation, and 3) evaluation. The role of those reference models is to identify the subjects to be checked and confirmed among the stake holders.

Modeling Stage

The reference model for the modeling stage is proposed for each category of the energy-saving ITS measurements; i.e. 1) improving driving behavior, 2) traffic control for intersections & highway corridors, 3) traffic management in network scale, and 4) TDM & modal shift.

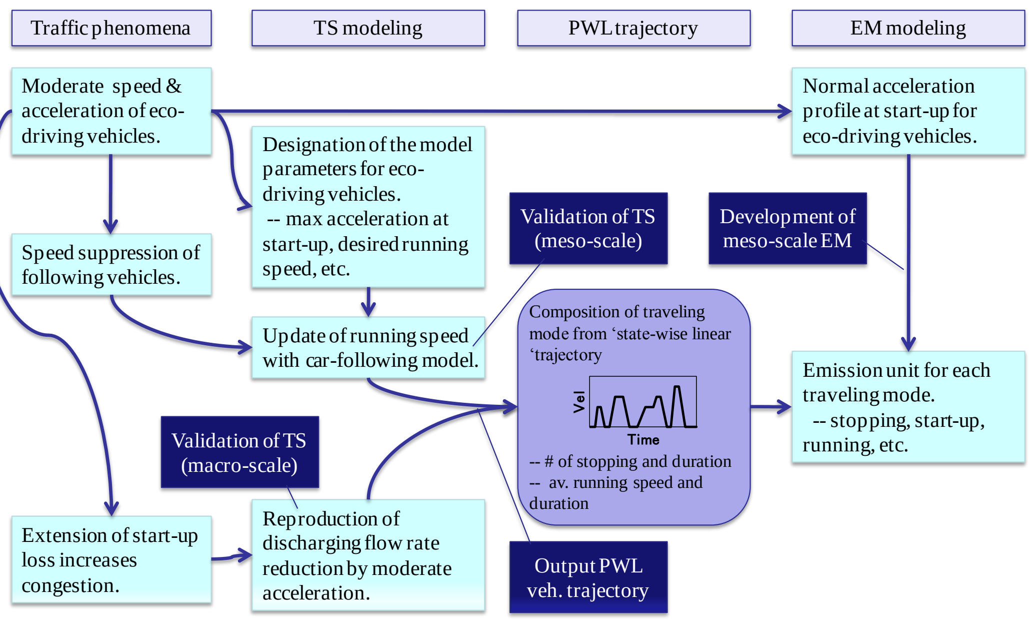

Figure 3: The reference model for the 'eco-driving' model

The reference models for those ITS measurements are formatted as follows. At first, the traffic phenomena to be considered are identified. How to model those phenomena in TS is subsequently described. Since we are endorsing the use of PWL trajectory to mediate TS and EM, it is to be described how the ITS measurement effects on the PWL trajectories output from TS. Finally, some of the traffic phenomena which are considered not in TS but in EM are described. In order to make a connection to the next ‘verification & validation’ stage, the items which are necessary to be checked in the next stage should be given comments. Figure 3 is an example for ‘eco-driving’ in the first category of the ITS measurements.

Verification & Validation Stage

TS is often criticized because of its black-box behavior. To overcome that criticism, we are promoting the use of TS through verification & validation to comprehend the models’ nature. Here, ‘verification’ means the examination if a model follows rules programmed into a computer as the developer intends. For instance, we may examine if the number of vehicles generated from an origin is exactly the same as the intended value following the probability distribution specified. The shockwave speed produced by a model may be checked if the speed matches with the kinematic theory. On the other hand, ‘validation’ is the examination if a model reasonably reproduces complex real phenomena. In the real world, we face a lot of traffic phenomena such as merging, diverging, weaving phenomena, etc., which are quite difficult to describe in a closed form equations. In the validation, we attempt to confirm the reproducibility of real complex traffic phenomena.

Figure 4 illustrates our VVD (Verify-Validate and Disclose) policy in so-called 'V-shaped' software development model. Here, let us add the ‘disclosure’ process to the normal V-shaped model. This means for any evaluation model, unless the result of the verification and the validation should be in public, we do not accept the use of such models.

So far, we have developed the 'Standard Verification Manual' and 'Benchmark Dataset' which have intended to verify and validate the model nature for the evaluation of ‘delay’ or ‘loss’. In the future scope, we will disseminate the extended manual to driving behavior level and prepare precise benchmark dataset for the validation of CO2 emission model in real world.

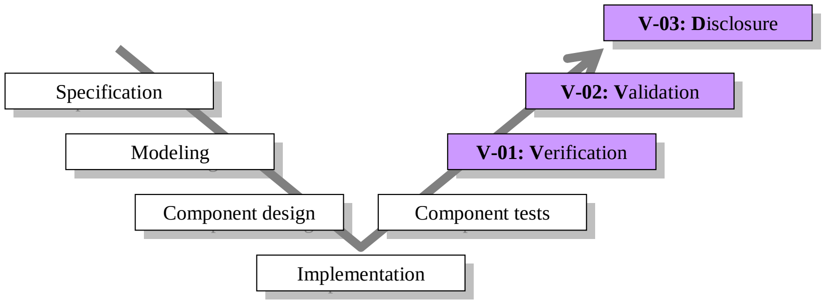

Figure 4: VVD policy in 'V-shaped' software development model

Evaluation Stage

The reference models for the evaluation stage depict the 'proper procedure' of TS and EM use. For this stage, we have proposed two types of the evaluation procedure; the integrated approach with total simulation and the expansion approach with partial simulation. In the former approach, TS may deal with large network which covers whole region/nation-wide area and all vehicle trajectories are to be provided to EM. Figure 5 illustrates the procedure of this integrated approach. In the latter approach to the contrary, TS covers some 'representative' small areas in the subject region/nation. The CO2 reduction estimated in the representative areas will be expanded to the whole region with proper procedure.

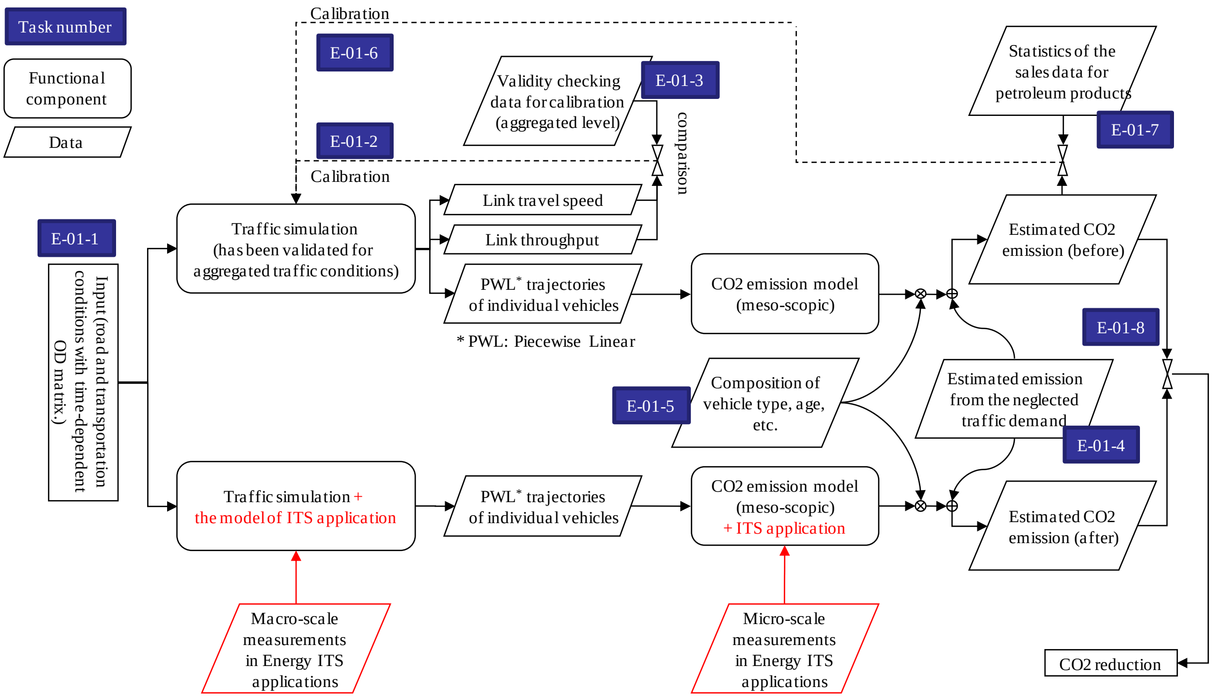

Figure 5: Evaluation process of the integrated approach with total simulation for region/nation-wide studies

FUTURE DISCUSSION

Our project aims to establish the reliable evaluation method in international context. In this sense, those idea presented in this paper are to be discussed and consented in our international collaboration scheme to which EU and US partners are participating.

We are also working on the development of our TS and EM associating model, which will represent the Japanese models, according to the proposed reference models. However, we will not force to use our model to EU and US sides. As we mentioned in this paper, we are intending to provide 'open' development scheme on the reference models, if they are approved internationally, anyone can develop the evaluation model.