DEVELOPMENT OF A HYBRID TRAFFIC SIMULATION FRAMEWORK FOR ENVIRONMENTAL EVALUATION FOR ITS APPLICATIONS

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ABSTRACT

The purpose of this paper is to introduce the development of a hybrid traffic simulation framework (HTSF) to evaluate ITS applications with CO_2 emissions. This study is a part of our themes in the Energy ITS Project, and we developed the prototype using this framework harmonized with CO_2 emission model (EM). The HTSF provides a simulation environment to combine three traffic simulation models in different resolutions. ITS applications should be evaluated comprehensively because there are many ITS applications which have different scales of impact. Therefore, the HTSF in this study is considered that the output of CO_2 emissions including a variety of impacts from ITS applications can be estimated for the target area. This study is a part of the researches in the Energy ITS project organized by NEDO (New Energy and technology Development Organization) in Japan.

BACKGROUND

First of all, we introduce the background of this study before the concept of the HTSF. One of the major topics in the Energy ITS project is to establish the rational procedure to estimate CO_2 emissions from automobiles. The Energy ITS project has been started in 2008, and we have been discussed about the evaluation procedure of ITS applications toward the goal of the project in our international collaboration scheme with EU and US partners. Fig.1 shows the research directories to establish the estimation method in the Energy ITS project.(1) In the study of the HTSF, we work on the traffic simulation technologies that can evaluate quantitatively ITS applications to reduce CO_2 emissions in automobile traffic. In addition, the requirements for the traffic simulation technologies to output the rational result of CO_2 emissions are discussed. After that, we develop the HTSF and the evaluation tool using the HTSF.

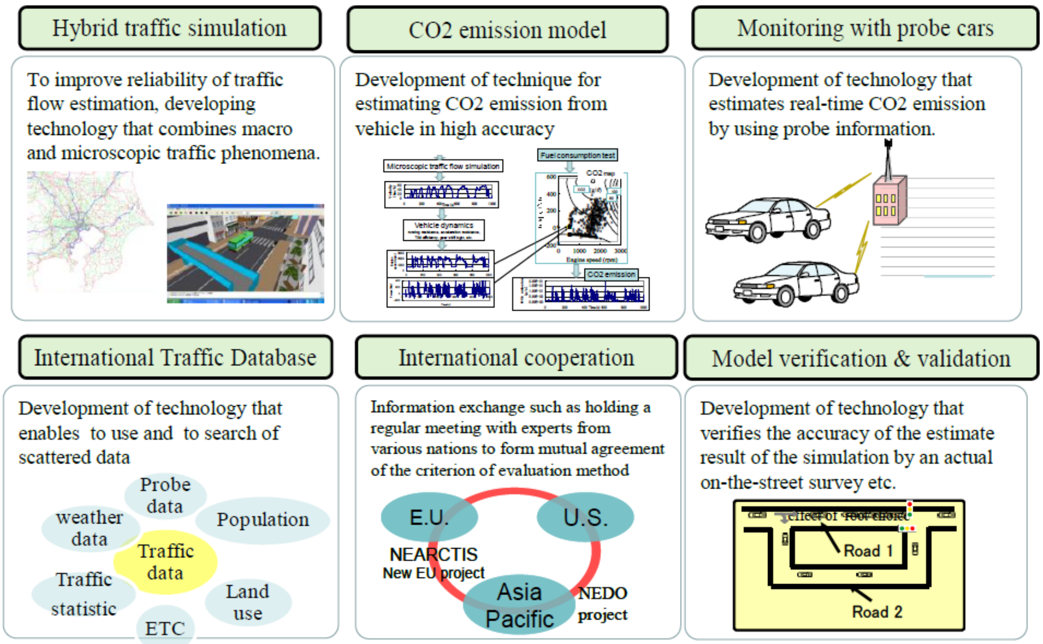

Fig.1 Research directories to establish the estimation method in the Energy ITS project

CONCEPT OF THE HYBRID TRAFFIC SIMULATION FRAMEWORK

Hybrid traffic simulation which considered the combination of the different types of TSs has been already discussed by some research. (2)(3)(4) And it is believed that the evaluation of CO_2 emissions using traffic simulation model is generally accepted. However, we should point out here that existing models by the combination of TS and EM are not considered the effect to CO_2 emissions by ITS applications. It is said that validation result of TS with EM is rarely found. The HTSF in this study is intended to evaluate ITS application which is expected to reduce CO_2 emissions. Therefore, the result of CO_2 emissions by the traffic simulation considering to the interactions of the impact on a macro scale and on a micro scale is required for the goal of this study. Furthermore, the verification and validation process are an important point for the reliable and quantitative evaluation. The HTSF in the Energy ITS project is developed based on the following keywords.

- Enlargement: to cover the whole Japan road network with mesoscopic TS for nation-wide case studies and to cut out partial networks for regional studies and give them base conditions (e.g. OD matrix) easily.
- Partial refinement: to embed a microscopic TS into a mesoscopic TS to reproduce fine grained traffic conditions when it is necessary.
- Real time: to monitor the present traffic conditions and CO_2 emissions by using real-time probe data.

"Enlargement" means the concept about the area scale for traffic simulation. The HTSF provides a capability to be able to simulate the arbitrary area as a part of a large-scaled traffic simulation network. "Partial refinement" describes the concept about the integration of different modeling levels of TSs. For example, a microscopic TS handle a part of an area represented by a mesoscopic TS with ITS Applications which are needed to handle detailed behaviors of vehicles. "Real time" is explained that the traffic condition can be represented in real time using the HTSF for the monitoring of CO_2 emissions. Fig.2 shows an image of the evaluation tool concept using the HTSF. First, ITS applications are modeled according to requirements for evaluation such as area scale and installed to each simulation models. After the installation, those applications are simulated by traffic simulators at different levels of traffic flow model in parallel when it is necessary. In this simulation, these simulators exchange the simulation result such as vehicle movements with route choices, traffic volumes and link travel times for every scan. Therefore, each simulation model on the HTSF can give traffic impacts with each other. And EM can be incorporated to estimate CO_2 emissions from the simulation results. Fig.3 shows the evaluation image using the HTSF.

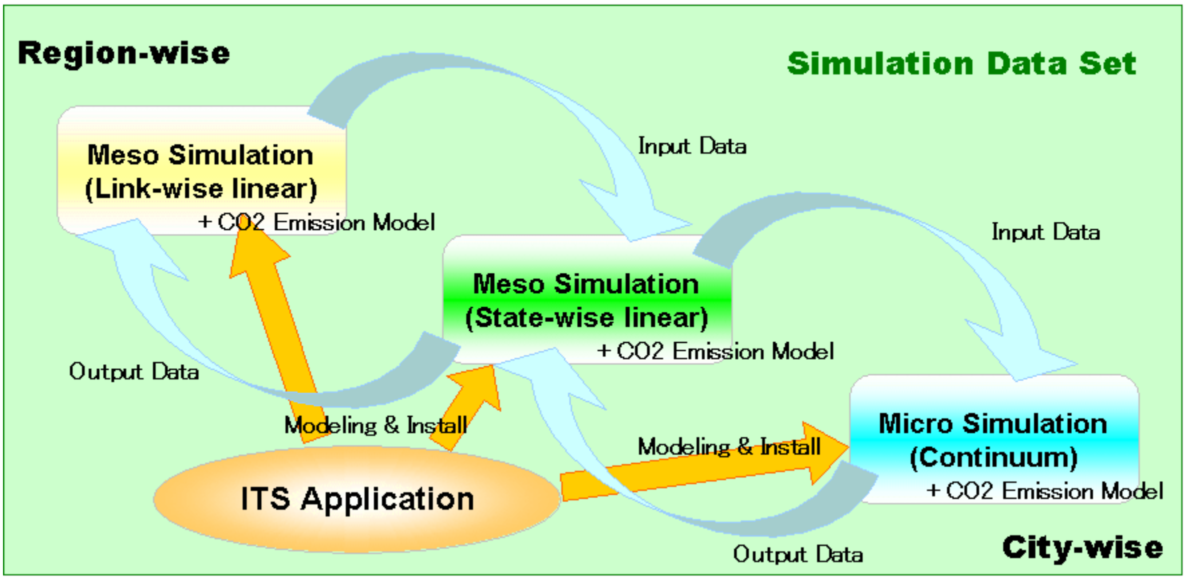

Fig.2 An image of the evaluation tool concept using the HTSF

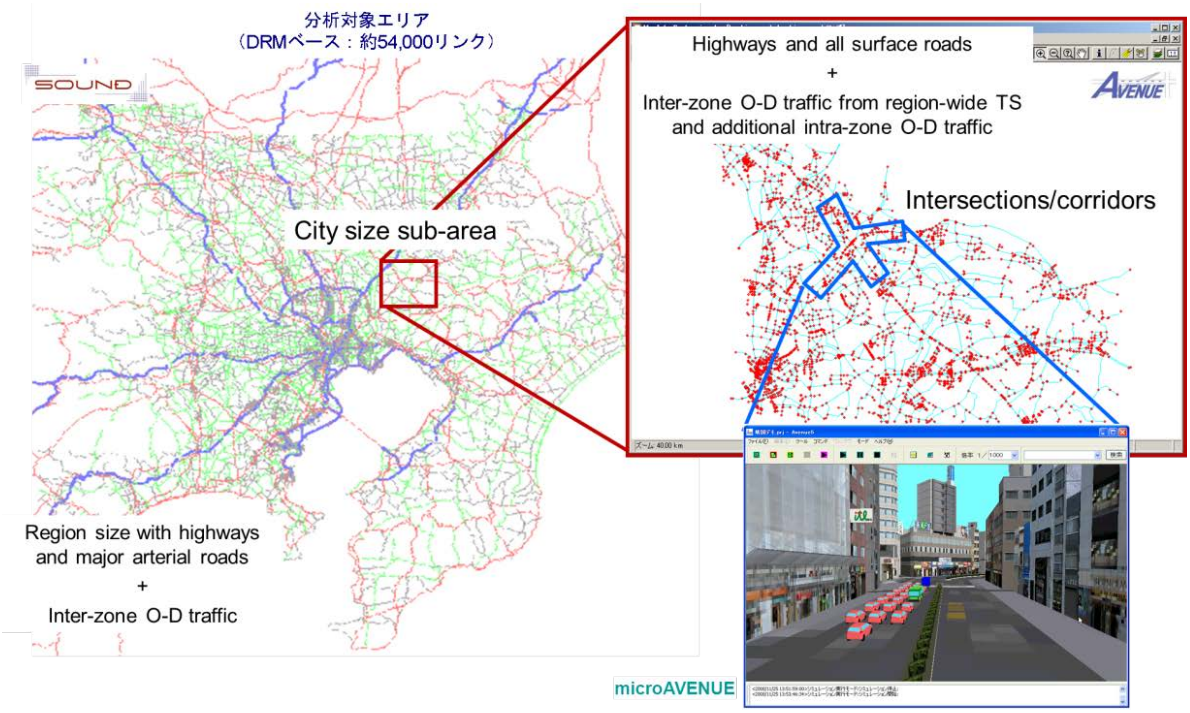

Fig.3 the evaluation image using the HTSF

Fig.4 shows the integration example of TSs using the HTSF. In this simulation, the vehicle information with vehicle ids, positions, current speeds and other attributes is shared by each TS on the HTSF. Vehicles in the simulation choose their routes considering a whole of the simulation network. The issues we discuss are the method of the model combination to solve the problem of the boundary condition between different traffic models.

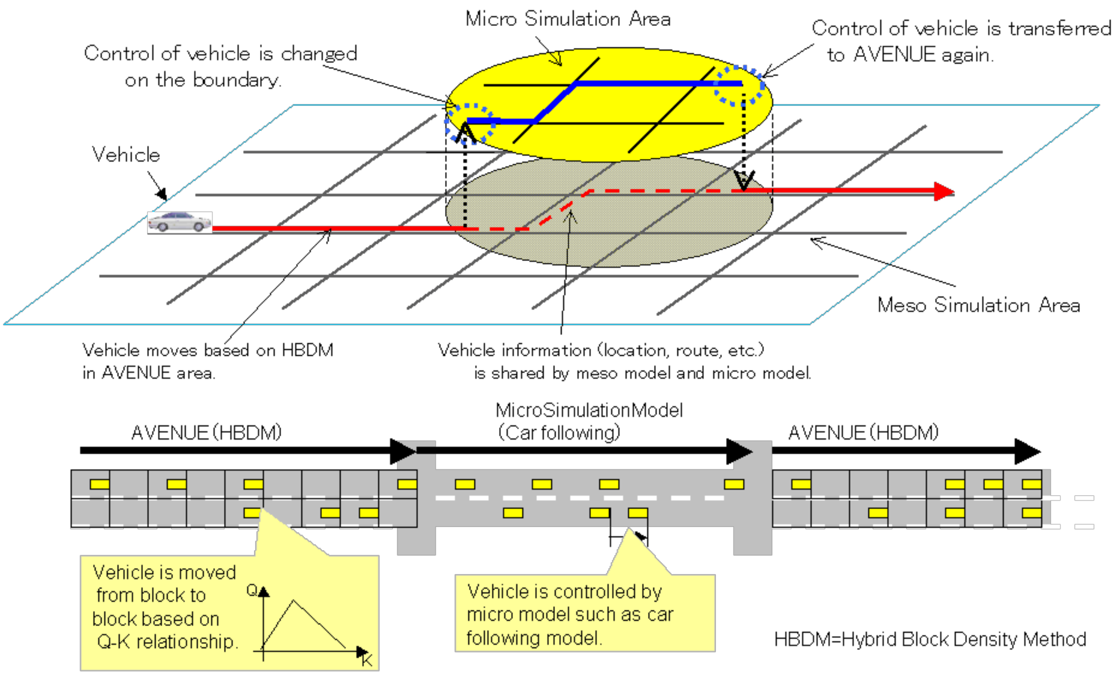

Fig.4 the vehicle moving by integrated models on the HTSF

TRAFFIC SIMULATIONS FOR THE INTEGRATION

In this study, we use the following TSs for the integration. Fig.5 shows the traffic simulation models for the integration on the HTSF.

- SOUND(5) : mesoscopic TS for region-wide road network
- AVENUE(6) : mesoscopic TS for city-wide road network
- MicroAVENUE : microscopic TS for the requirement for more detailed vehicle behavior.

SOUND is a mesoscopic TS that vehicle is moved by the queuing model based on the Simplified Kinematic Wave Theory(7)(8). AVENUE employs the Hybrid Block Density Method (HBDM) (6). HBDM is the traffic flow model which treats traffic flow as continuum. MicroAVENUE is a microscopic TS based on the car following model that the speed of vehicle is determined by the target headway with some parameters such as target speed, max acceleration.

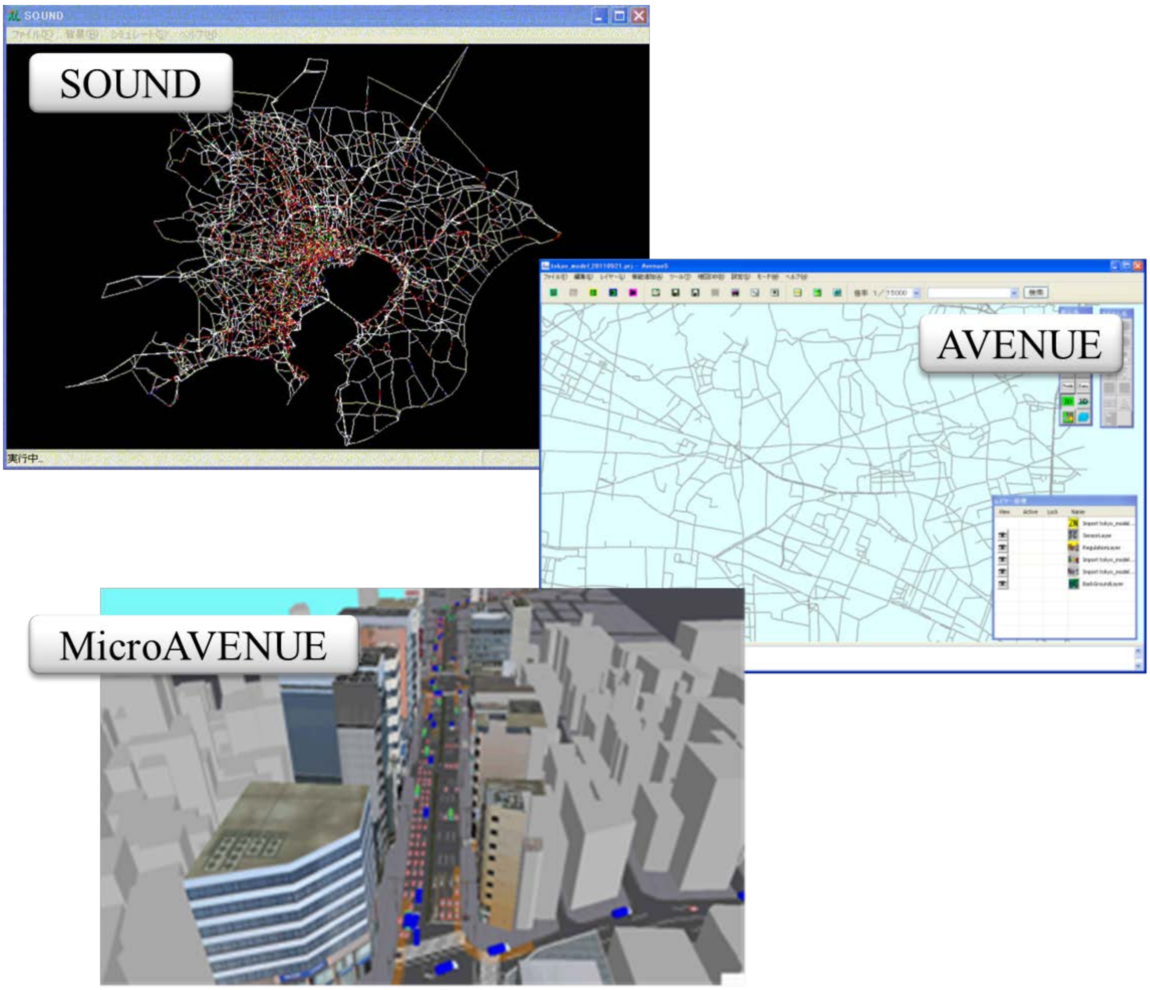

Fig.5 Traffic simulation models for the integrate on the HTSF

INTERFACE BETWEEN TS AND EM (STEPWISE SPEED FUNCTION)

To estimate CO_2 emissions by the harmonization of TS and EM, there are many combinations of TS and EM. Fig.6 shows the combinations between TS and EM. Three types of vehicle trajectory of TS can generally be divided as shown by Fig.6. Link-wised linear trajectory is drawn based on link enter time and link exit time. However it is difficult that the acceleration points and the deceleration points can be understood. Fine grained trajectory is the most detailed data that the acceleration pattern can be calculated at high resolution. However, fine grained trajectory cannot be outputted by mesoscopic TS. State-wised linear trajectory can be calculated by the both of TS types. The detailed vehicle behavior is not referred, but the state of vehicle behavior (acceleration, running deceleration and stop) and its position can be used as the interface with EM. On the other hand, EM can be chosen according to the input data of TS. To evaluate ITS applications with CO_2 emissions, the effect of the acceleration pattern by ITS should be considered because some of ITS applications (e.g. support system of EcoDriving) are needed to control the driver's acceleration pattern. Therefore, we choose the combination of state-wised linear trajectory and developed Stepwise Speed Function (SSF) as the interface between TS and EM from the point of view from the hybrid traffic simulation. And meso-scaled EM to harmonize with TS using the HTSF was also developed in the Energy ITS Project.

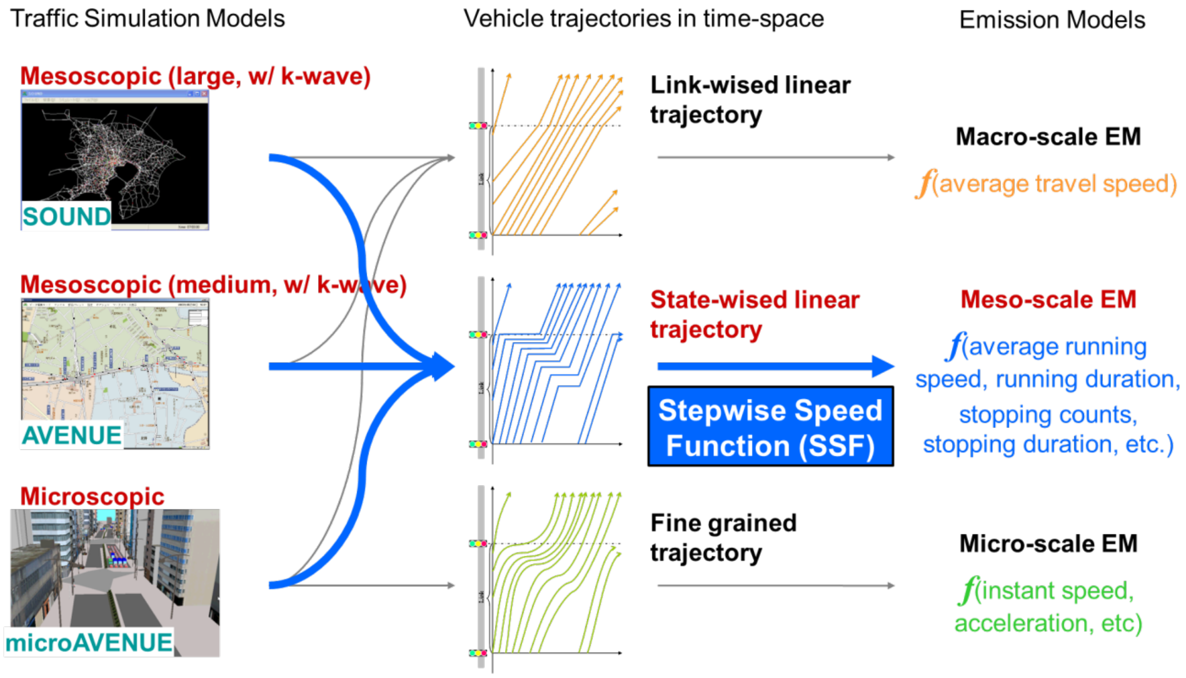

Fig.6 Combinations between TS and EM

Fig.7 shows the image of SSF. And Fig.8 shows the generation process of SSF. SSF has an average speed of vehicle from start to stop with the additional information which includes number of acceleration, number of deceleration, road types (e.g. highway, regular road), longitudinal grade and etc. SSF is calculated by the trajectory of each vehicle in TS. SSF is not only a simple and low-sized interface but also the acceleration can be considered in some level. Therefore, it is said that SSF is applicable for large size of simulation network to evaluate ITS applications. On the other hand, EM which has the interface for SSF accumulates SSF pattern from the observed data using probe car in real word.

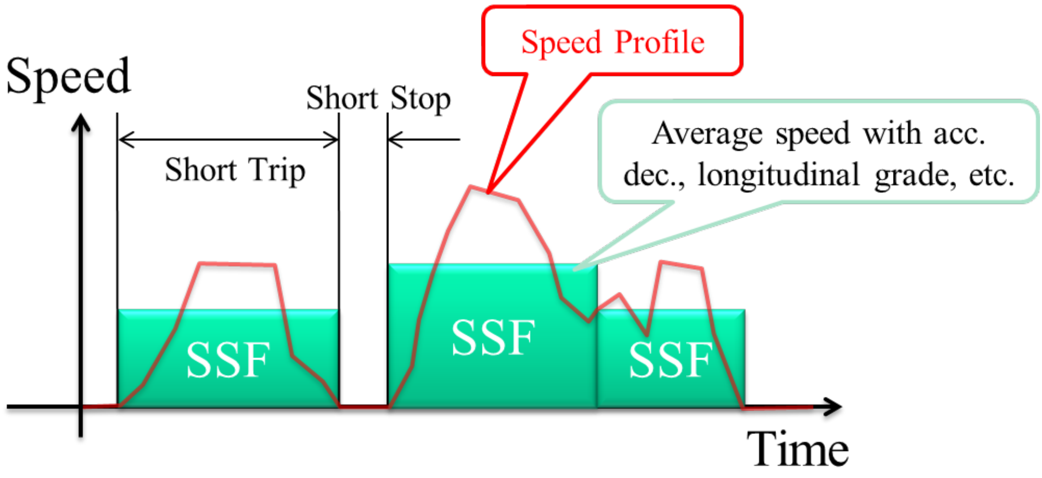

Fig.7 Stepwise Speed Function

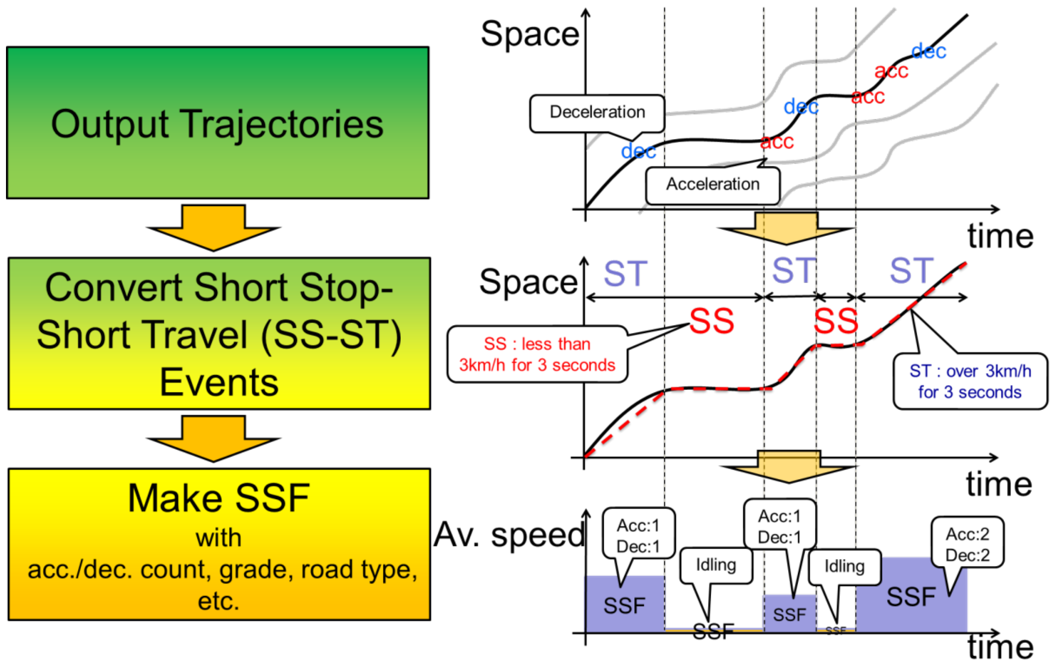

Fig.8 Generation process of SSF

For the implementation of SSF, we use TS and Map data base (DB) as shown in Fig.9. Firstly, vehicle trajectories are made with vehicle information in TS. Secondly, SSFs are generated using vehicle trajectories referring to Map DB. And finally, SSFs are used by EM to estimate CO_2 emissions. In this study, the additional information for SSF includes road type and longitudinal grade. SSF is able to have more information from Map DB if other information is needed to add to SSF.

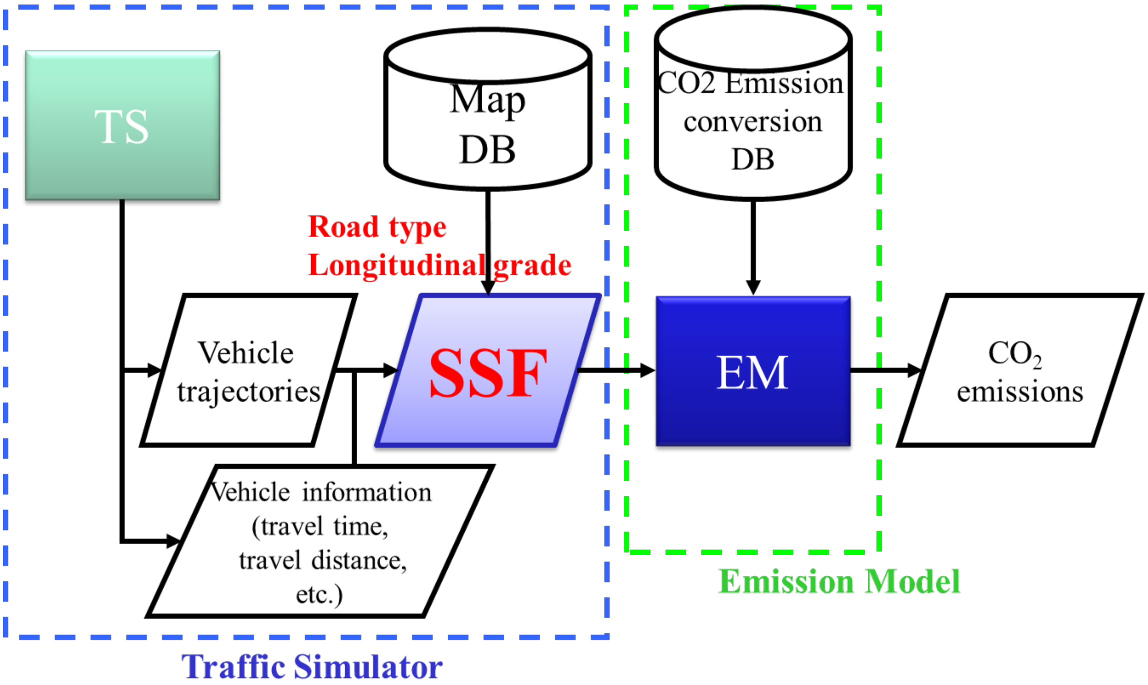

Fig.9 Implementation of SSF for the harmonization of TS and EM

VERIFICATION AND VALIDATION OF THE HTSF

The important point of the verification for the hybrid type of traffic simulation is that the shockwave propagation should be expressed based on traffic flow theory when the traffic queue is spilled back from a bottleneck to upstream over the boundary between traffic models. Fig.10 and Fig.11 shows a verification example using a simple network of the test case. The shockwave of traffic can be checked by the vehicle trajectories over the boundary between mesoscopic TS and microscopic TS. On the other hand, it is said that the continuity of trajectories on the boundary should be verified, especially for EM.

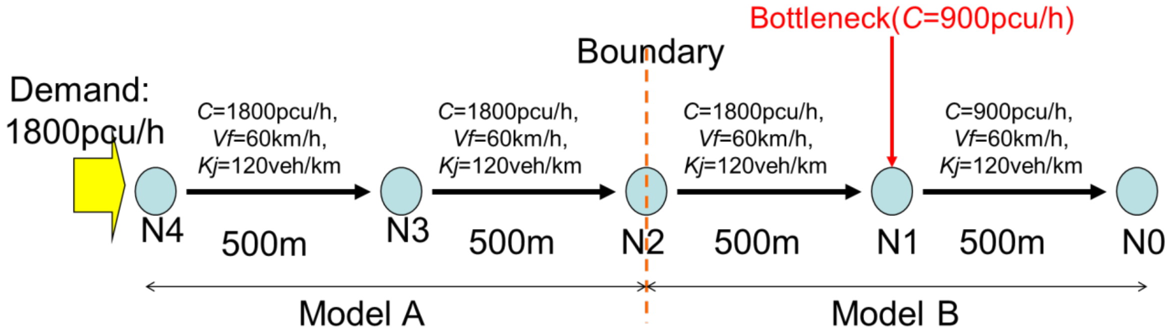

Fig.10 A case setting for the verification of the HTSF

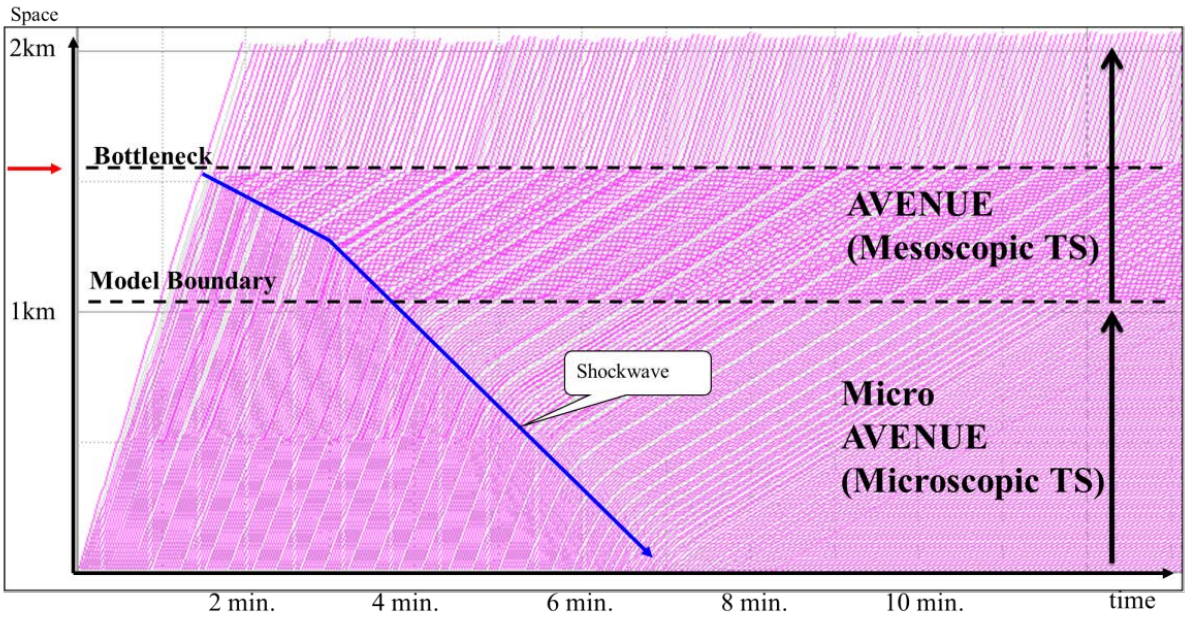

Fig.11 A verification example using a simple network

On the other hand, the validation of each simulation models is done. As an example, the validation results of SOUND and AVENUE are disclosed on the website of 'Traffic Simulation Clearing House' (http://www.jste.or.jp/sim/index.html). And the development of validation manual for the evaluation tool integrated TS and EM have been discussed in Energy ITS project (9). After the verification of our evaluation tool using the HTSF, the simulation results such as traffic volume, vehicle trajectories and CO_2 emissions are compared with our data set in Tokyo.

FUTURE WORKS

In this paper, we introduced the hybrid traffic simulation framework that integrates the different types of TSs. We developed a prototype of evaluation tool for ITS Applications using the HTSF. As the future works, we practice some case studies of the evaluations of ITS applications after the verification and validation. And the evaluation process of ITS application is described through the case studies.

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