A MANUAL OF VERIFICATION PROCESS FOR ROAD NETWORK SIMULATION MODELS - AN EXAMINATION IN JAPAN

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SUMMARY

This paper at first introduces an examination in Japan to standardize traffic simulation models. The basic idea of the standardization here is to estimate abilities of existing models how to reproduce traffic conditions through verification and validation. Verification implies qualifying tests using virtual data sets in order to make a connection between the simulation model and the traffic-engineering theory clear, while validation means an evaluation process with real world data. Subsequently to the general introduction, the verification process will be detailed with its philosophy and basic test configurations to verify models' functions concerning to 1) vehicle generation, 2) bottleneck capacity at simple road sections, 3) capacity of merging/diverging areas, 4) traffic jam growing/shrinking with propagation of shock waves, 5) capacity of left/right turn at an intersection, and 6) drivers' route choice behavior. In the last part of this paper, we briefly state the on-going project to compare some popular simulation models in Japan.

INTRODUCTION

Necessity of Standard to Evaluate Traffic Simulation Models

Nowadays, we may find dozens of simulation models in all over the world. In general, network simulation models handle with wide urban area containing various traffic situations, so that their algorithms to reproduce traffic flow is necessary to be simplified in some degree. Even in so-called "microscopic" models, vehicles are just moving by a-priori car following principal that does not give a guarantee to be applicable in overall traffic context. Therefore it is impossible for simulation models to perfectly reproduce traffic conditions, and we would like to know how they do well.

Developers of simulation models would have provided the idea how to work the calculation algorithms. However it is difficult to understand everything from literatures only. We still have less information on what model parameters they have or how the traffic conditions they will reproduce, as if their hearts are "black box". Such situation might be a barrier for users to select an appropriate simulation model for their subject.

One measure to remove this barrier is to apply simulation models to real traffic data and to validate their performance of reproduction. The importance of model validation using real traffic data was suggested[1)] so far. However, this sort of filed application still gives us site limited aspects. When the developer of each simulation model individually achieve validation, we still face the difficulty to compare several models and to choose appropriate one among them. We need some sort of standards to evaluate the simulation models.

Process of Simulation Model Development and Application

In order to cope with this problem, we have proposed the standard certification process for the development of simulation models. The certification process contains five stages described as follows. Through the last two stages, a simulation model adduces evidence of its availability and then certifies itself.

<u>Specification</u> – *Determination of model requirements and specifications*
If a model wants to be widely used, there must be a common recognition on its specifications, i.e. system input and output items and its behavior guaranteed by the system. For this purpose, requirements must be organized to determine what kind of traffic phenomena must be handled on the basis of consideration of application purpose, and then determine the model specifications at this stage.

<u>Modeling</u> – *Contrivance of the model operation principle*
Contrivance of the model operation principle consists of the process of constructing the algorithm complying with the model specifications, and of deciding how such algorithm is to be incorporated into the model. Here the originality of each developer plays an important role even when the same specification is complied with.

<u>Implementation</u> – *Programming and debugging*
This process consists of programming to run the operation principle contrived in the previous stage on a computer and debugging to check if the computer operates according to the algorithm. Debugging must be distinguished as an operation different in nature from verification described in the next.

<u>Verification</u> – *Qualify tests with virtual data*
This stage is to confirm that the implemented model can reproduce the traffic phenomena considered in the model specification stage, thereby verifying that the operation principle is justified. In this case, an object of comparison with the simulation result is the traffic engineering theory established already. Generally, verification involves extraction and verification of individual highlighted phenomena, one by one, while using virtual data with ideal conditions so that they can be free from various actual restraints, such as the data accuracy, reliability, availability, etc.

<u>Validation</u> – *Evaluation of validity using real world data*
This stage is to evaluate the practical applicability of the model using data available in an actual world. Assume that the adequacy of the model operation principle has been verified in the previous stage. The model is not considered to be practically applicable, however, if the

model specification itself is incomplete or the actual traffic situation can not be sufficiently reproduced due to the realistic problem on input data acquisition or parameter calibration. Furthermore, the model performance as a system should also be confirmed, such as whether or not the execution of the model can be performed within a practically applicable time.

Japanese Activity for Standardization of Traffic Simulation (WG5/WS)

The standard certification process described above is currently discussed in the working group (WG5/WS) under the technical committee of Japan Society of Civil Engineers to get mutual agreement among traffic engineers. WG5/WS is conducting “Clearing-House” of information about traffic simulation models[2)] on Internet. The developers and the users of simulation models can publish their experience with verification and validation results through the clearing-house. Following materials are also available on the clearing-house at present.

Draft Version of the Manual of Standard Verification Process for Traffic Simulation Models[3)]

This manual describes minimal verification items mainly for so-called network simulation models. The subsequent chapter of this paper focuses on the main purports of the verification manual and then give an outline of the substantive verification steps.

Standard Benchmark Data Set for Validation of Traffic Simulation Models

Validation requires data on simulation inputs including traffic demand and operation as well as highly reliable data representing the traffic situation to be compared with the simulation result. Such data collection has been a substantial burden for model developers, hindering validation. With this background, we have proposed the desirable validation process using common benchmark data sets, which is collected from real world with highly reliable preciseness[4)]. WG5/WS now prepare five data set for different categories of road networks like urban streets, inner-city highways, etc.

MANUAL OF STANDARD VERIFICATION PROCESS

Fundamental Concept

Verification is a sort of virtual test using ideal network and demand configurations to qualify basic phenomena on road traffic. Simulation has an advantage in applicability to theories while theories can give us a general criterion to evaluate the traffic phenomena. Accordingly, verification is not to expect exact agreement of the simulation result with the theoretical values. The objective of verification is to define the model characteristics while confirming correlation with or difference from the theory. Establishing this linkage will provide us very helpful information to understand the model characteristics. At the same time, it is considered important to define the relationship between certain model parameters and model behavior.

We may now find two categories of network simulation models. One is that maintain traffic flows with vehicle lists or fluid approximation according to the macroscopic flow characteristics, like flow-density or density-speed relationship, given to each link or section. Another type of simulation models is employing vehicle driving behaviors including car following and lane changing. Here, let us say former as Q-K type and latter as C-F (car following) type.

The biggest difference of these two types is that Q-K type explicitly, or implicitly, gives the capacity to a link or a section, while C-F type basically does not have a parameter directly implies the capacity of link. As the concept of verification is to compare the simulation models' behavior with the established theory that is normally on macroscopic view, the detailed description of verification step would be separately defined for each category, i.e.:

a) For the simulation models of Q-K type, the verification implies that the simulation result really agrees to the given flow characteristics. In this sense, the verification process of this type is to be said as a kind of self-consistency check.
b) For the simulation models of C-F type, the model parameters are concerning to individual driver's characteristic. Therefore, the verification process of this type should make clear the relationship between those model parameters and the flow characteristic reproduced by the simulation. In this sense, we may say the verification is a sort of sensitivity analysis.

Features to be Considered through Simulation

We have included six basic features in the verification manual, which should be at minimum considered by the network simulation models.

<u>Generation of Vehicles and Flow Conservation</u>

For implementation of simulation, it is necessary to generate the traffic at the entry end according to the arrival distribution of vehicles from outside the study area. Some type of pattern such as random arrival or uniform arrival to be assumed according to the type or road concerned and the size of traffic volume. Verification process requires whether the generation pattern assumed in the model really achieved. It should be also checked whether the number of vehicles generated in a certain time period is equal to the given volume.

Once a vehicle generated, it must not disappear until it reaches its destination. Even in the case that vehicle queue spills out of study area, newly generated vehicles are added to the end of the point queue outside the network and will flow into the network after sufficient time period. Simulation models, so that, must keep this flow conservation law not only at every links but also outside of network.

<u>Bottleneck Capacity / Saturation Flow Rate at Link's Downstream End</u>

As the discharging flow rate from a bottleneck section like sags or tunnels contributes to the reproduction accuracy of the delay caused by the congestion at the bottleneck, it is essential that the capacity of the bottleneck should be reproduced in a stable manner during simulation.

Not only sags or tunnels but also merging and diverging sections can be the most remarkable bottleneck of highways. At the congesting merging section, the travel time on each approaching branch may vary with the merging ratio if the capacity of the merging section is constant. Contrary, the capacity of the diverging section is constrained by the capacities of downstream links and may change depending on the proportion of the demand to each branch. The verification step includes these merging and diverging configurations.

Even on surface streets in under-saturated conditions, a vehicle may have the delay coming from the stop and go at signalized intersections. The outflow from an intersection continues at the saturation flow rate till vehicles retained during the red phase are gotten rid of. It is important to clarify how the saturation flow rate is reproduced in the simulation model same as the bottleneck capacity.

<u>Growing and Shrinking Traffic Jam Consistent with Shock Wave Theory</u>

When traffic jam beginning at a bottleneck grows to the upstream link, the traffic that need not pass through this bottleneck may be also affected. As a difference in the jam's growing/shrinking speed results in difference in the degree of influence on the total delay upon whole network, it is important to reproduce this phenomenon by using physical-queue to reasonably maintain the traffic density of congestion. The verification of this phenomena is made by comparing the shock wave speed observed during the simulation with the one derived from the shock wave kinematics, as shown in Fig.1 .

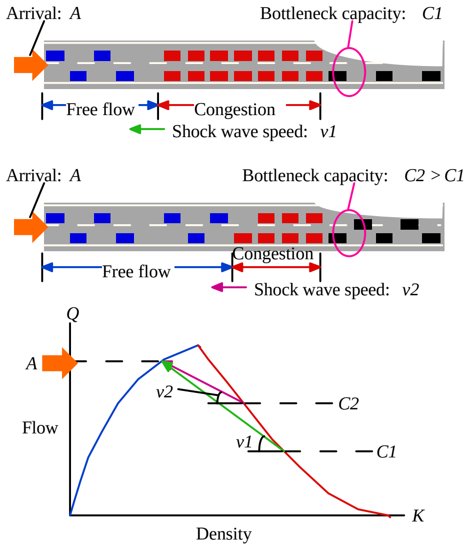

Fig.1: The growing speed of jam is determined by the arrival demand and the bottleneck capacity.

For surface streets, on the other hand, even if a signalized intersection is under-saturated, the vehicle queue grows and shrinks in every cycle. The tail of the queue moves with some time lag from the begging of green phase because of drivers' response delay at departure. When two signalized intersections are close along a street, this time lag and the offset of signal phases are strongly affected to the throughput along the street. Therefore, the simulation model that is considering signal control effect must reasonably reproduce this phenomenon including shock wave propagation.

<u>Gap Acceptance of Right(Left)-Turn at a Signalized Intersection</u>
In ordinary streets, it is a daily observation that vehicles waiting for right(left)-turn in the signalized intersection hinder travel of following vehicles, resulting in congestion. Such vehicles are waiting to find out a gap in the opposing straight-through traffic in the green phase. Model verification is made by changing the demand of opposing straight-through traffic and model parameters to define how decline the capacity of yield right(left)-turn.

<u>Drivers' Route Choice Behavior</u>
Modeling for drivers' route choice behavior considered in simulation is classified as follows:

a) Dynamic route choice model not incorporated
b) Dynamic User Optimal (DUO) principle incorporated
c) Dynamic User Equilibrium (DUE) assignment incorporated
d) Probabilistic route choice incorporated

Of these models, the one using a) above is considered applicable to evaluation of the short-term traffic management that need not consider the route of drivers, or to a network without allowance for route choice. Verification of these models is not necessary because it is equivalent to the verification of merging/diverging section.

On the other hand, the simulation model using standards of b) c) and d) adopts a framework in which drivers select the route on the basis of presented route cost. This type of model is frequently used to evaluate the operation policy of dispersing the traffic spatially by means of informative service or road construction. Verification of these models can be made using a simplified network, e.g. with two routes for one O-D pair, to avoid the difficulty to figure out the theoretical flow pattern to be compared with the simulation result. It is also interested during the validation that the change on the settings of simulation model such as the update interval of route costs and the location where the drivers can receive the information on the costs will affect to the flow pattern.

Description of Standard Verification Process

As mentioned before, the detailed verification step is separately described for Q-K type and C-F type with different fashion. In order to show how the verification of these two types are different, the verification of bottleneck capacity is illustrated as an example in the next two sections.

<u>Verification of Bottleneck Capacity (Q-K type)</u>

Given the sufficiently large demand to the bottleneck according to the procedure described below, verification is made whether the flow ratio on the downstream side is stable at the given bottleneck capacity. You may read the meaning of "self-consistency check" from the last step iv) .

i) A network to be used consists of links whose downstream ends become bottlenecks as shown in Fig.2 (a). Set the model parameter so that the bottleneck capacity becomes 800, 1000, and 1200 [pcu/hr]. The capacity is set to be 2000 [pcu/hr] for other sections.
ii) The traffic demand of 1500 [pcu/hr] is provided so that congestion occurs always in the bottleneck.
iii) Simulation is made for one hour using respective model parameters and the throughput volume on the downstream side of bottleneck is recorded.
iv) As shown in Fig.2 (b), the throughput volume cumulative curve is plotted, and verification is made to see if the given bottleneck capacity is really achieved.

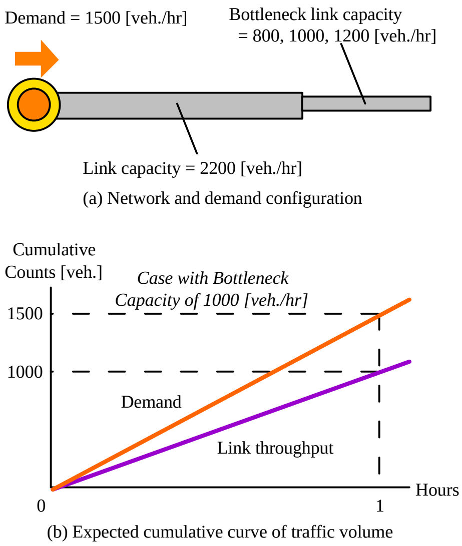

Fig.2: The verification step of the bottleneck capacity for Q-K type simulation models.

<u>Verification of Bottleneck Capacity (C-F type)</u>

Before to start verification, the major model parameters should be listed up with their default values and plausible setting ranges, and roughly classified into those related to the driving behavior and those concerned with a location and road section. In this section, a follow type model is assumed, which has the model parameters shown in Table 1. Simulation is made for a simple road network as in Fig.3.

Since this process is actually to determine what kind of traffic flow characteristics of a model demonstrates when certain input data and parameter settings are used, the average Q-K curve is derived according to the subsequent steps by changing the parameter settings for all combination of their default, minimum and maximum values.

Table 1: The model parameter of the C-F type simulation model assumed here.

	Parameter Name	Default	Minimum	Maximum
a) For driving behavior of vehicles				
a1)	Responce delay	1.0 sec	0.7 sec	1.5 sec
a2)	Desired headway	2.0 sec	1.7 sec	3.0 sec
a3)	Max. acceleration	2.0 m/sec2	1.8 m/sec2	2.5 m/sec2
a4)	Desired speed	60 km/hr	40 km/hr	100 km/hr
b) For demand				
b1)	Compositon ratio of drivers group of which the driving characteristics are different	Set freely as required		
c) For link performance				
c1)	Limit speed	60 km/hr	40 km/hr	100 km/hr
c2)	Gradient	0 %	-6 %	6 %
c3)	Driveway width	3.5 m/lane	2.75 m/lane	3.5 m/lanez

i) Set the traffic demand at some level and start simulation.
ii) Wait till the link becomes a "steady state", then observe the cumulative throughput volume at upstream and downstream ends of the link during some time period.
iii) Take the average number of vehicles on the link from these two cumulative volume

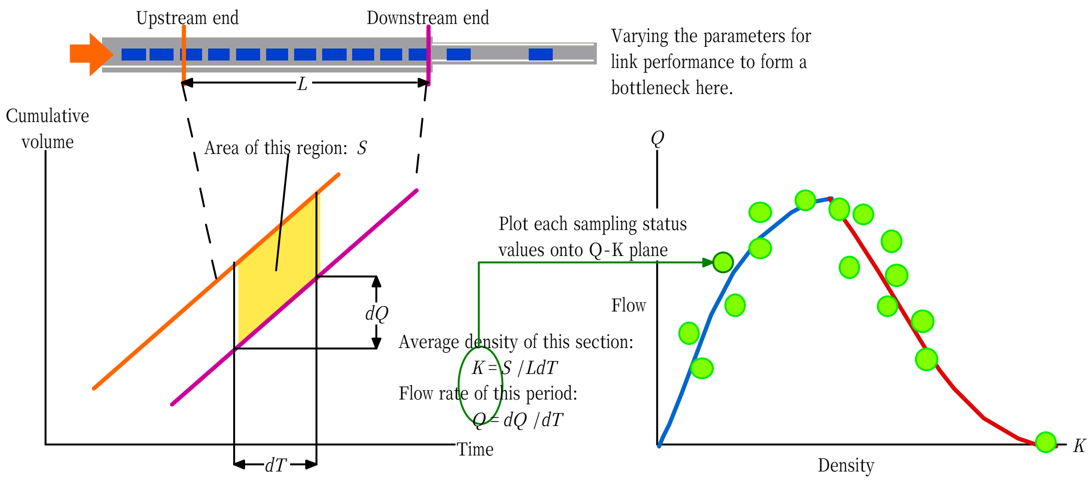

Fig.3: The verification step of flow characteristic of C-F type simulation model.

curve, and calculate the average traffic density on the link. Then, plot the result on the Q-K plane.

Lay all plots of Q-K plane into one, of which the parameter settings on driving behavior are the same but the settings on link performance are different. The interpolate curve represents the average Q-K curve for the parameter setting on driving behavior.

Other steps in the verification of C-F type are based on this “derived” flow characteristic related to the model parameter settings. Therefore, the verification of this step must be made at first.

CONCLUSION AND FUTURE TOPICS

In this paper, we have presented the basic idea of the certification process for the simulation models through verification and validation. Also, the concept and the outline of the manual of standard verification process currently examined in Japan is introduced. The verification manual is published[3)] through the “Clearing House” of simulation models[2)] on the Internet. The URL is http://trans1.ce.it-chiba.ac.jp/ClearingHouse/main.html.

Several simulation models which are practically used in Japan will qualified with the verification process and will be evaluated its performance in WG5/WS. We have now seven pilot models, such as AVENUE[5)], SOUND[6)], tiss-NET[7)], Paramics[8)], CORSIM[9)], REST[10)] and SIPA[11)], to be verified along the verification manual and validated with benchmark data set. Only the result of AVENUE[12)] is available at present. The further discussion in WG5/WS is expected that for to comprehend the results of the verification studies, and to estimate the characteristics of each model. Also, we will afford the movement of this standard certification process for other simulation models world-wide.

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