

Cover Page

Abstract ID	8052
Paper Title	A Model System for Evaluating Road Improvement Plan by Combining Traffic Assignment and Traffic-Flow Simulation
Contact Author	Ryosuke ANDO (author1)
Email	ando-ryo@katahira.co.jp
Phone	+81-52-451-0234
Fax	+81-52-451-0311

A MODEL SYSTEM FOR EVALUATING ROAD IMPROVEMENT PLAN BY COMBINING TRAFFIC ASSIGNMENT AND TRAFFIC-FLOW SIMULATION

Ryosuke ANDO
Chief
Department of Transport
Nagoya Branch
Katahira & Engineers Inc.
WestPoint 1413, Tsubaki-cho 14-13,
Nakamura-ku,
Nagoya 453-0015, Japan
Tel: +81-52-451-0234
Fax: +81-52-451-0311
E-mail: ando-ryo@katahira.co.jp

Masashi ICHIKAWA
Engineer
Department of Transport
Nagoya Branch
Katahira & Engineers Inc.
WestPoint 1413, Tsubaki-cho 14-13,
Nakamura-ku,
Nagoya 453-0015, Japan
Tel: +81-52-451-0234
Fax: +81-52-451-0311
E-mail: ichikawa@katahira.co.jp

Abstract: To evaluate road improvement planning, we usually use the results obtained by applying traffic assignment model in a macro level and the computed saturations of intersections in a micro level. However, there are disadvantages with each of them. Thus, we propose a combined model system with a traffic flow simulation as a decision-making support system for planning. The model system includes traffic assignment, computing of intersections' saturations and traffic simulation. To be used as an evaluating model, we propose a group of evaluating indices when we apply the combined model system for the evaluation of the road improvement planning in practice. Furthermore, as an example, we applied the model system for the evaluation of the improvement planning of National Road No. 156 in Gifu City.

Keywords: support system for planning, evaluating model, traffic-flow simulation, road improvement, traffic assignment

1. BACKGROUND AND OBJECTIVES

National Road Number 156 ("R156" as an abbreviation) passes through the eastern area of Gifu City from Ginan Interchange to Seki City (see Figure 1). At the Ginan Interchange, R156 crosses with National Road Number 21 and 22. As an arterial road, there is the heavy traffic in the urban section of R156. Especially, around the Irifune Intersection, the traffic jam happens everyday during the peak hours. One reason is because the elevated part with 2 lanes joins with the ground lanes to the intersection. Thus an effective measure has been expected for a long time.

Up to now, to forecast the traffic demand with a road improvement plan, Chubu Regional Bureau of Ministry of Land, Infrastructure and Transport of Japan generally applies the so-called Method of Best 3 Routes for Toll Roads Based on the Minimum Sacrifice Route Approach. Further, the planner computes the traffic flows to the intersection during the peak hours by using peak-hour-factor etc. and then computes the saturation of the intersection to evaluate the geometric design of intersection and the road improvement plan.

Here are two problems can be pointed out. One is that the Method of Best 3 Routes for Toll Roads Based on the Minimum Sacrifice Route Approach is a model system for the traffic assignment in a wide area network. Therefore, when being applied to the local area such as the analysis of the intersections, we may not obtain the satisfactory answers

affected by the network parameters used for the wide area. Another problem is that the timely traffic changed in seconds or minutes cannot be computed exactly since the traffic assignment is computed by using the daily origin-destination traffic volume (OD table).

Thus, we have to say that the Method of Best 3 Routes for Toll Roads Based on the Minimum Sacrifice Route Approach is not suitable with the evaluation of the traffic jam measures or the improving traffic services. On the other hand, the approach of saturation computation limits us to analyze the intersection one by one separately, so we cannot use it to analyze the continuous intersections, especially we have to give up in case of discussion of the reasonable share between the elevated lanes and the ground lanes.

On the basis of the above background, one of the objectives of this study is to establish an integrated model system by combining the traffic assignment model, the saturation computation approach and a micro-simulation model, which is generally used to analyze the traffic flow phenomenon. Another objective of the study is to propose the evaluation method and the evaluation indices for the road improvement planning. Furthermore, we apply the proposed model system and the evaluating method/indices for the evaluation of the improvement plans having been made for the urban section of the R156. That shows the effectiveness of the model system and the method/indices.



Figure 1 Object Area

2. THE INDIVIDUAL METHOD/APPROACH /MODEL

2.1 Method of Best 3 Routes for Toll Roads Based on the Minimum Sacrifice Route Approach

For traffic assignment, we applied the Method of Best 3 Routes for Toll Roads Based on the Minimum Sacrifice Route Approach. This method had been proposed in 1997 at the Report on the Project of Travel Demand Forecasting implemented by Chubu Regional Bureau of Ministry of Construction (see Chubu Regional Bureau of Ministry of Construction), and it applied both of the equations of the speed ~ flow ($Q \sim V$) and the equations of the conversion for the incremental assignment.

This method was proposed as the common approach for the traffic assignment in the area that the Chubu Regional Bureau controlled. Thus all of the work offices had been asked to apply it for the study on the road improvement planning. The advantage of the method is that the analyst can choose three routes of toll road, instead of only one choice before, as the objective routes to which the traffic flow converts from the non-toll roads. The algorithm of choosing the three routes is based on the concept of the minimum sacrifice. We choose one route with the minimum sacrifice by changing the time-values 5 times. The vehicle types are defined as “passenger cars”, “small trucks”, and “large trucks”. The equations of the speed ~ flow are defined on the basis of the

classes and ranks of roads, the number of lanes, the land-use status of surroundings, the vehicle types and the permitted speeds by law. The percentages of conversion from the non-toll roads to the toll roads are computed by the time lag of the two routes and the time values etc.

2.2 Saturation Computation Approach

A grade crossing is generally analyzed by using the saturations, which can be computed one by one for all signalized grade crossings. The work flow chart of the approach is depicted in Figure 2. The satisfactory value of the saturation is defined as 0.9 for the crossing planning. The advantages are that we can consider not only the plane plan of the crossing but also the signal indication and the signal cycle. The disadvantages of the approach are that we cannot consider the interactions in a group of the successive crossings.

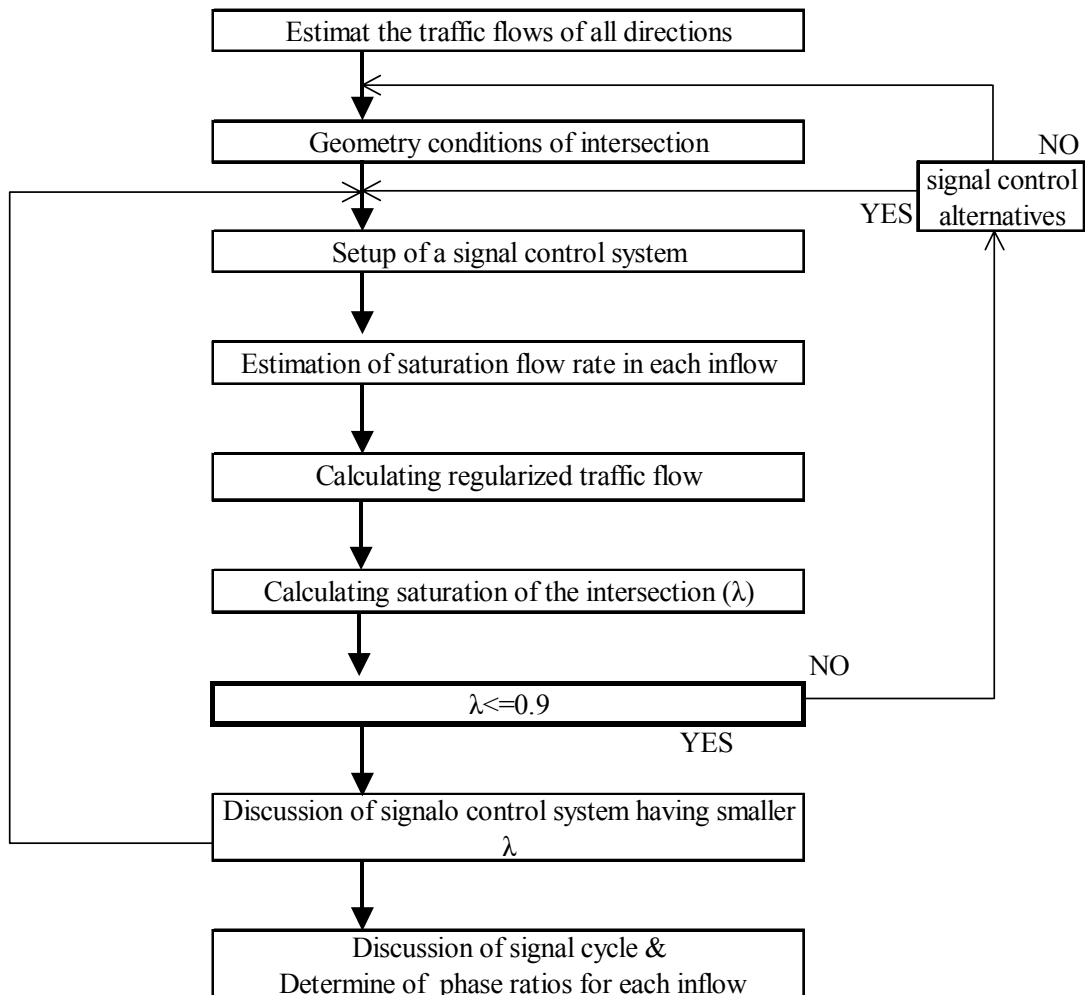


Figure 2 Flow Chart of Analysis

2.3 Micro-Simulation Model

2.3.1 NETSIM: A Micro-Simulator Existing in Market

The main advantages of the micro-simulators are that you can view the traffic flow by a computer and understand the traffic situation by some indices very directly. Comparing to the congestion index computed in terms of the result of traffic assignment, the saturation index obtained from the saturation computation approach, that, the delay time and the queues at the crossing given as the results a micro-simulation, is easier to be understood for all of planners, users and residents.

There are many micro-simulators that have been developed and can be bought in the Japanese market. You can choose any one from NETSIM, AVENUE, CONTRAM, SATURN, DESC Model, DYTAM-I, INTEGRATION, DYNASMART, FHMA Model, SOUND, NISSAN Traffic Flow Simulator etc.

Our choice for this study was NETSIM. The NETSIM is especially suitable for the simulation of the urban traffic system in detail. By the simulator, we can catch the movement of each vehicle up every second and easily to reenact the scene in the street and make the analysis of traffic flow in the road network. As a summary, the reasons can be given as the followings.

- Achievements: NETSIM was developed by FHWA and has been applying in not only U.S.A. but also many other countries in the world, so that it has been revised many times and has been made to be suitable with the Japanese traffic laws.
- Price: it costs Japanese Yen 900,000. It was cheaper than the other micro-simulator softwares sold in Japan, therefore most of planners can buy one set easier.
- Maneuverability: by using the newly developed Editor for Input Data, any user can easily input data for simulating.
- Expression of traffic flow: the users of simulator can reenact the behavior of vehicles at the crossings and the road network in a microscopic and probable viewpoint.
- Expression of traffic control: signs and signals control can be easily reflected as the input data in the simulation.
- Parameters: the users of simulator can set many parameters such as categories of vehicle type, characteristics of vehicles, type of drivers' behaviors (active, normal, passive), expecting speeds etc.
- Outputs: the users can choose what they want from the list of outputs that includes delay time, stop time, travel time, travel distance, average speed, maximum queue, amount of fuel used, amount of gases exhausted etc.

2.3.2 Procedure of Applying the NETSIM in the Study

By applying NETSIM, we can simulate the real traffic situation and analyze the reasons of traffic jam observed at the Irifune Intersection. Further, we can simulate the traffic flows hourly when we implement the improvement plans with the Irifune Intersection. On the basis of the results of simulations, we can compare and evaluate the improvement plans by using the indices such as the delay time. Moreover, we can propose the new improvement plans to be compared and evaluated. The procedure of applying the NETSIM is as the followings.

- Realizing of present traffic situation: to understand what we have realized and not

according to the traffic survey that were carried out in the passed year, and to prepare the data for checking the simulation

- Preparation of data for the simulations: to prepare the basic data about the roads such as number of lanes, width of lanes, speed limitations and the road network et al., furthermore the data of traffic volumes generated from the nodes around the objective road network
- Implementation of simulation: to implement the simulation by using the data collected from the traffic survey and estimate the parameters of simulation model, and then to carry out the simulations respective with the improvement plans
- Evaluation of the improvement plans: to evaluate comprehensively the road improvement plans on the basis of the analysis of the results obtained from the simulations

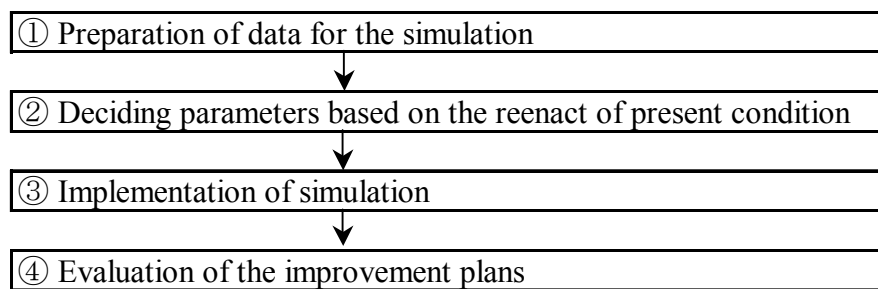


Figure 3 Flow Chart of the Traffic-Flow Simulation

3. INTEGRATED MODEL SYSTEM

3.1 Main Body and Heading

By systematizing the individual method, approach and model having been stated respectively in Chapter 2, we establish an integrated model system as shown in Figure 4.

The procedure of establishment is as follows.

- Estimating a day-traffic volume in the target year, by applying traffic assignment method with the future road network in terms of the road improvement plan.
- Computing the traffic flows by hours, vehicle types and directions.
- Deciding the intersection geometry and the signal control on the basis of saturation of intersections computed by using the above results of the traffic volumes.
- Applying traffic-flow simulation by inputting traffic volumes, and setting up the intersection geometry and signal control conditions into traffic-flow simulation model.
- For the further evaluation, after evaluating the saturation of intersections, we adjust signal control mode, cycle length and make simulation again.
- Extracting the best plan through the comprehensive evaluation for all improvement plans.

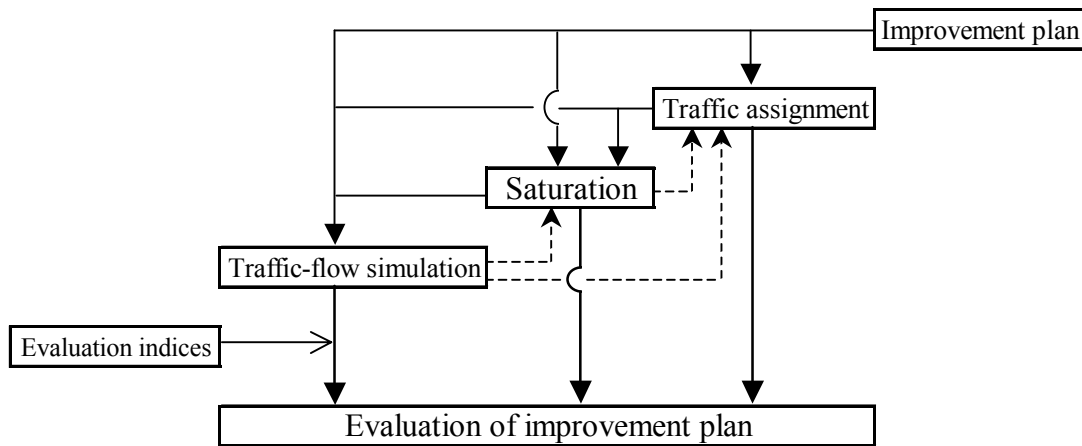


Figure 4 Flow Chart of Evaluating Improvement Plan

4. PROPOSE OF EVALUATION INDICES TO EVALUATE ROAD IMPROVEMENT PLANS USING MICRO-SIMULATION MODEL

To evaluate road improvement plan comprehensively, we propose the following evaluation items and indices (see Table 1).

Table 1 Evaluation Items and Indices

	Evaluation Items	Evaluation Indices
1	Level of service and improvement level	Delay time because of stopping
2	The longest vehicle queue	The longest vehicle queue in each direction
3	Average speed and travel time in intersections	Average speed in each direction
4	Traffic behavior	Displaying in animation

1) Level of service and intersection improvement level:

Here, the concept of level of service in Highway Capacity Manual (see National Research Council) and the intersection improvement level index being proposed in terms of the concept of level of service are used for evaluation.

Level of service of signalized intersection is defined by ‘delay time’ that results when a control signal causes a lane group to reduce speed or to stop.

And, effect of improvement plan is evaluated by improvement level index as shown in following equation (1).

$$P_1 = (d_b - d_a) / d_b \times 100 \quad (1)$$

P_1 = index of improvement level (%), d_b = delay time before the improvement (s/veh), d_a = delay time after the improvement (s/veh)

- 2) The longest vehicle queue:

Because most of vehicles are passenger cars, we consider the spacing as 8 meters.

- 3) Average travel speed and travel time in intersections:

Average speed of all vehicles flowing into the intersection from each direction, and travel time in intersections is calculated on the basis of the longest vehicle queue.

- 4) Traffic behavior:

By displaying in animation, we can describe the traffic behavior in each intersection.

Table 2 LOS criteria for the signalized intersections

LOS	Delay time per vehicle (s/veh)
A	10
B	> 10-20
C	> 20-35
D	> 35-55
E	> 55-80
F	> 80

Source: Highway Capacity Manual 2000

5. APPLICATION TO EVALUATE IMPROVEMENT PLANS FOR R156

Four cases being examined as the improvement plans are shown in Table 3. Here, we consider Iwado elevated bridge and the paralleled plane part on R156 as Section 1, and Iwado tunnel part on R156 as Section 2 (see Figure 1).

Now, we evaluate the improvement plans of R156 in proportion to the integrated model system we have proposed in chapter 3.

5.1 Evaluation by Traffic Assignment

At first, we carried out the traffic assignments respective with all improvement plans, and then calculated the ratio (=assigned volume/standard design volume) of each section by using the standard design volume given in Road Structure Ordinance of Japan (see Japan Road Association).

Table 3 Improvement Plans

Contents of improvement plan	
Present condition	Section 1: Provisional 2 lanes (Iwado Ramp - Irifune Ramp) Section 2: Provisional 2 lanes
Case 1	Section 1: 4 lanes (one lane bound to south is touched to Ishinaga) Section 2: Provisional 2 lanes
Case 2	Section 1: 4 lanes (one lane bound to south is touched to Ishinaga) Section 2: 4 lanes
Case 3	Section 1: To North: make use the present 2 lanes; To South: 3 plane lanes Section 2: 4 lanes
Case 4	Section 1: Provisional 2 lanes (Iwado Ramp - Irifune Ramp) Section 2: 4 lanes

Finally, as depicted in Figure 5, the comparing results show that the Assigned Volume/Standard Design Volume Ratio in all 4 cases are under 1.0 for almost all sections. Thus, it is difficult to judge which plan to be best one in terms of the traffic assignment results.

5.2 Evaluation by Computed Saturations

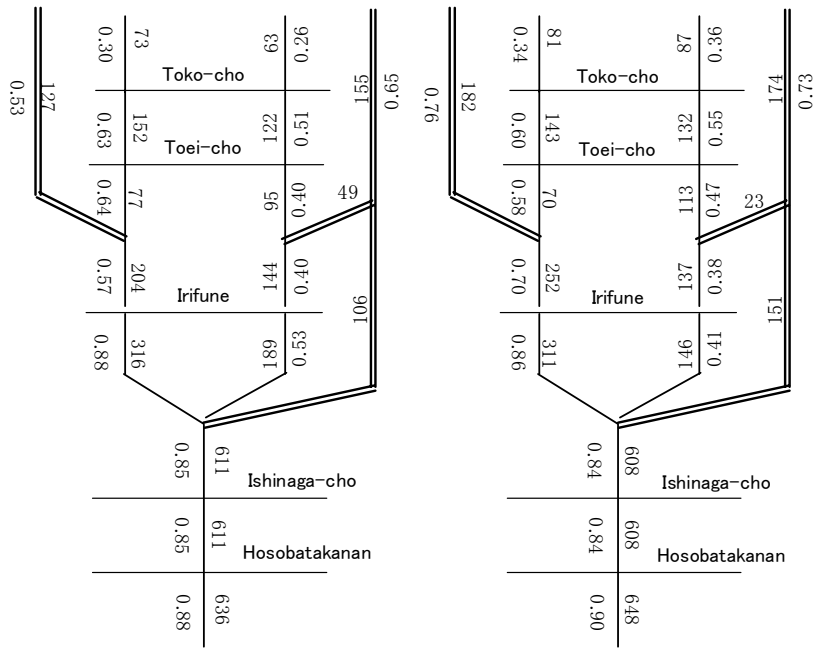
We computed saturations for all intersections respective with each improvement plan. The hourly traffic flows by the vehicle type for each direction were calculated on the basis of equation 2. We applied the traffic assignment result obtained in Section 5.1. And we adapted right/left turn ratios to calculate the traffic flows in each direction.

$$\text{Hourly Traffic Flow (veh/h)} = \text{day traffic volume} \times (\text{ratio of peak hour} / \text{ratio of daytime to nighttime}) \times (\text{D value}) \times (\text{correcting factor}) \quad (2)$$

*) Ratio of peak hour and ratio of daytime to nighttime are obtained from the traffic senses (see Japan Society of Traffic Engineers (2001)). We assume here that the traffic flows do not reach its peak at the same time, so we use (ratio of peak hour between 18pm–19pm)/(ratio of peak hour between 8am–9am) as the correcting factor.

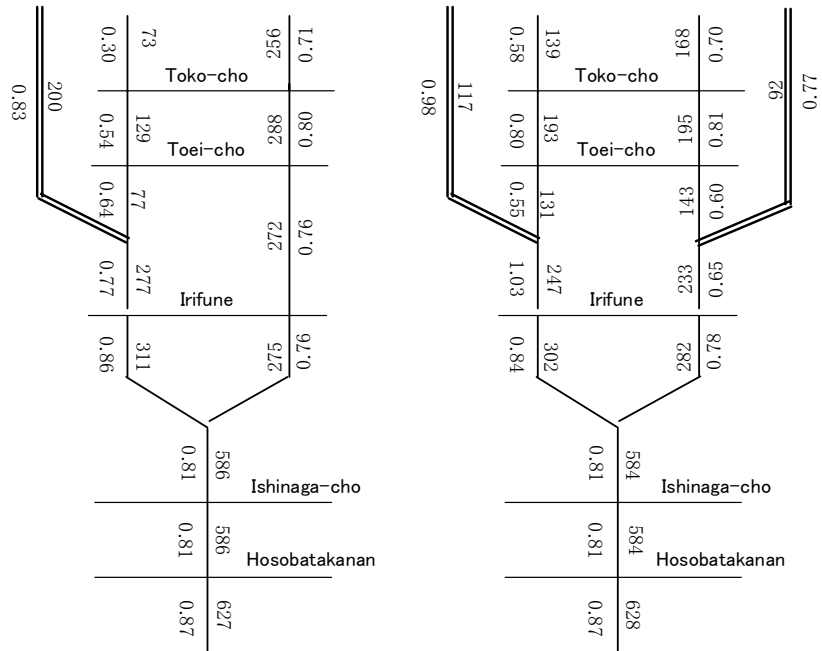
As a result, the saturation of Toei-cho in case 4 exceeds 0.9 (see Table 4). But, in other cases, the saturations at intersection are all under 0.9.

We could compare case 1-3 and case 4 by saturation computation, but it is hard to find superiority among case 1-3.



case 1

case 2



case 3

case 4

Above: The Assigned Volume (hundred vehicles/day, in 2004)
 Below: The Ratio of Assigned Volume/Standard Design Volume

Figure 5 The Result of Traffic Assignment

Table 4 Saturations of Each Intersection

	Irifune	Toei-cho	Toko-cho
Case 1	0.741	0.645	0.623
Case 2	0.741	0.645	0.623
Case 3	0.686	0.738	0.815
Case 4	0.688	0.917	0.789

5.3 Evaluation by Micro-Simulation

5.3.1 Estimation of Parameters

For the 3 intersections (Toko-cho intersection, Toei-cho intersection, Irifune intersection) at the Iwado elevated bridge area of R156, traffic survey had been undertaken in 1999/9/21 (Tue) 7:00-9:00. Here, we estimate parameters by reenacting present situation using this observation result. For recreation of present condition, we discussed and decided the road condition and traffic condition given in Table 5 and Figure 6 as the input data.

Table 5 Input Data of Road Condition and Traffic Condition

Lane	Number of lanes, right/left turn lanes
Signal	Control signal, cycle length, offset
Percentage of large vehicles	Setup as the observed traffic flows in each direction
Free flow speed	Legal speed is equal to the 85% tile-value of real speed, so we set free flow speed as 118% of legal speed: 40km/h 45km/h, 50km/h 60km/h, 60km/h 70km/h

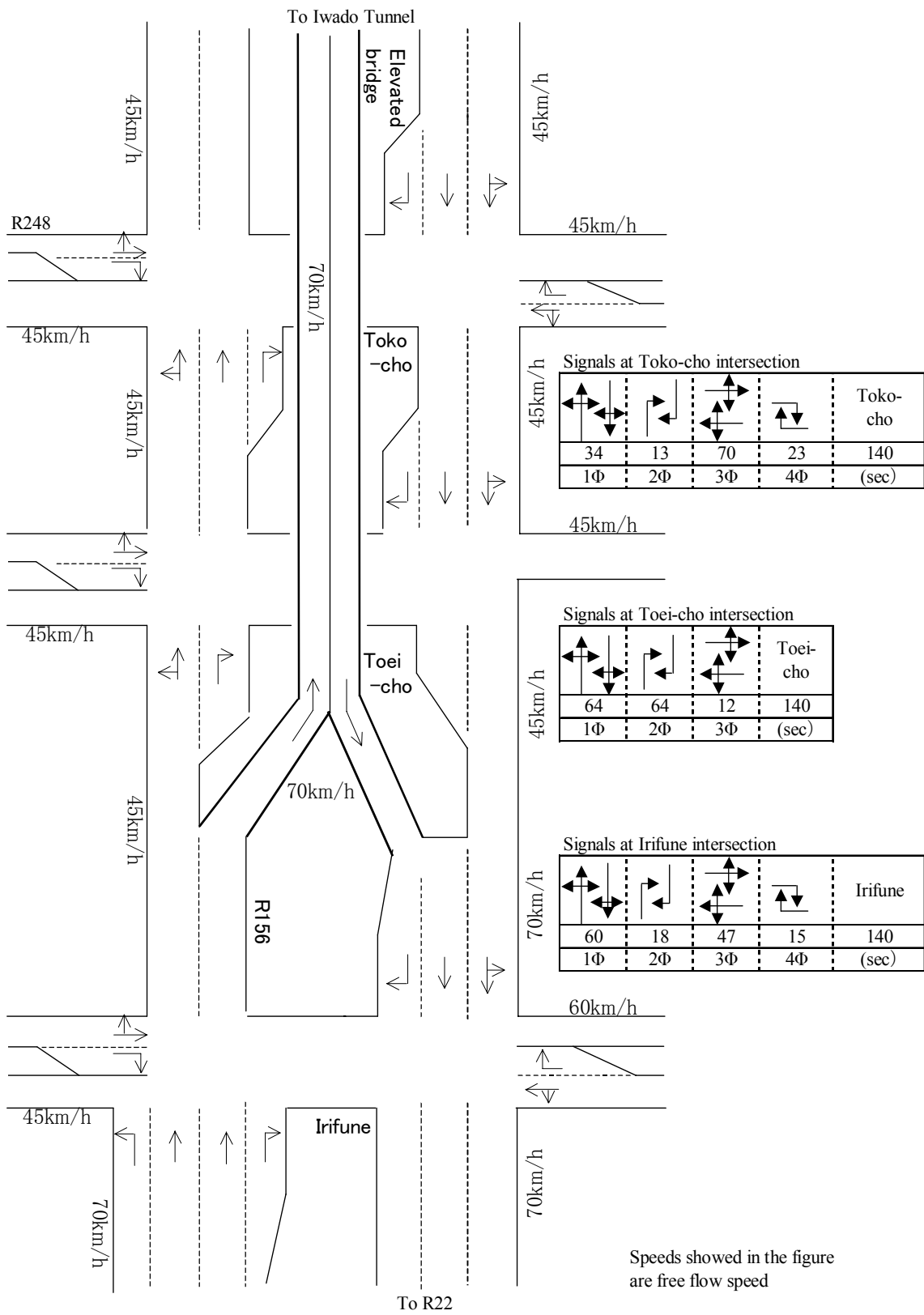
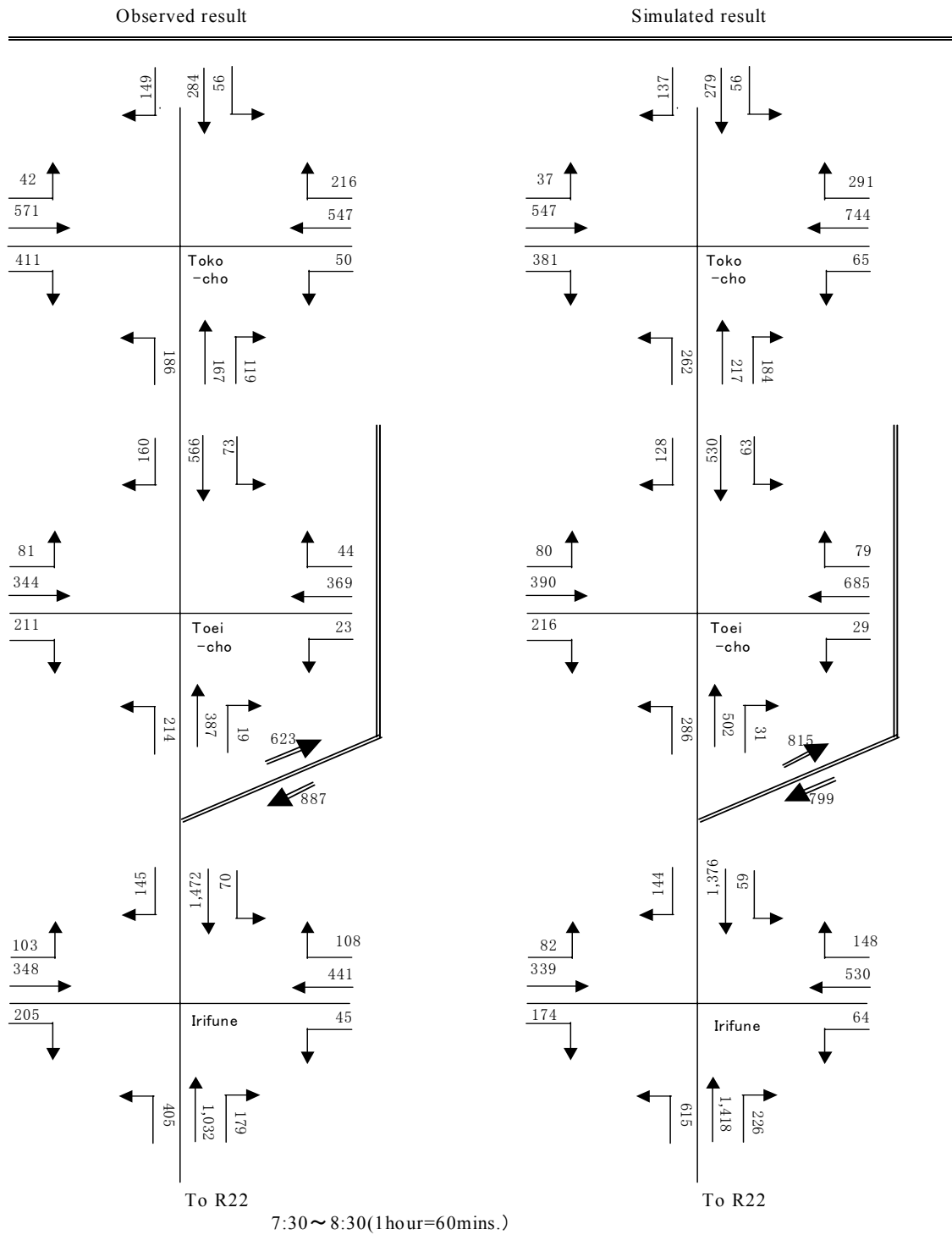


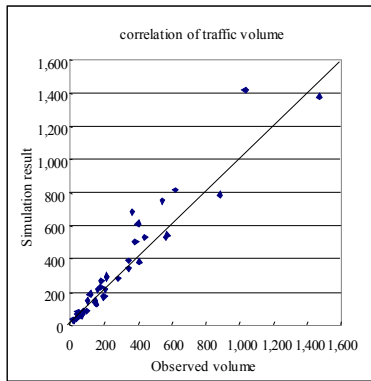
Figure 6 Road traffic condition

We checked the reenact of the traffic situation by comparing the observed result and simulated result of the traffic flows in each direction of all intersections (see Figure 7) and computed the correlation of both results (see Figure 8).



*)entrance and exit traffic of elevated bridge is assumed as the difference of the traffic to the north at Irifune intersection and the traffic toward north at Toei-cho intersection

Figure 7 Observed Result and Simulated Results



Correlation=0.96

Figure 8 Correlation of Observed Result and Simulated Results

In addition, we decided the parameters (see Table 6) of the micro-simulation model through repeating the simulation until we got a satisfactory reenact of traffic.

Table 6 Estimation Results of Parameters

Discharge Headway	1.8 sec
Start-up Lost-time	2.0 sec
Length of Passenger Cars	5 m
Length of Trucks	8 m
Acceleration of Passenger Cars	10.9 km/h/s
Acceleration of Trucks	5.6 km/h/s
Maximum Speed of Passenger Cars	129 km/h
Maximum Speed of Trucks	109 km/h
Safety Coefficient for Changing Lane	0.9
Other Parameters	Using default values of NETSIM

	e.g., Headway for changing lanes=3 sec
	Percentage of Cooperating Drivers=50%

5.3.2 Conditions for Micro-Simulation

Combining the parameters estimated above, we input and setup the hourly traffic volume on the basis of the traffic assignment, the road geometry, the signal control parameters obtained from the computation of the saturations for all intersections, and so on.

5.3.3 Evaluation of Road Improvement Plans

We evaluated the road improvement plans synthetically in terms of all indices

approached in the previous chapter (see Table 7). As a result, we treated Case 2 is the most effective plan. Some distinctive features of Case 2 are summarized below.

- 1) Level of service and the intersection improvement level indices:
 - At Irifune intersection, the 'Delay Time' is shortened by 15 sec/veh from 117.2 sec/veh to 101.6 sec/veh. This is the smallest value among 4 cases, so the Money Cost of the time-loss in Case 2 is estimated as 20,258 thousand yens which is the lowest value, too.
 - At the other intersections, for the north-south direction, the improvement level indices are also high.
- 2) The longest vehicle queue:
 - The vehicle queue became shorter at all intersections.
 - Especially, with the off-lump at Irifune Intersection which was regarded as questionable, there is the most remarkable improvement that the vehicle queue was shortened by 424m. Furthermore, the traffics bound to north was shortened by 360m at most.
- 3) Average speed and travel time in intersections:
 - The mean speed at the Irifune off-lump was up by 36km/h, and the travel time was shortened by 5mins.
 - For the north-south direction of the Irifune intersection, the mean speed was up by 8 km/h, and the travel time is shortened by 4mins.
 - At other intersections, mean speed were also up for the north-south direction.
- 4) Traffic behavior:
 - At the Irifune intersection, traffic flowing from the elevated bridge was lower, and the vehicle queue was also shorter than the present condition.
 - At the elevated bridge being over the Irifune intersection to the Ishinaga intersection, there were much traffic, and it flows intermittently.

5.4 Comprehensive Evaluation

For each improvement plan, we evaluated the results of traffic assignment, the saturation and traffic-flow simulation by the comprehensive judgment of rankings. (see Table 8)

- For traffic assignment, evaluation was made by the ratio of traffic volume/standard design volume. All cases showed the results being smaller than 1.0, so we considered them all equal.
- For Toei-cho in Case 4, the saturation exceeded 0.9. For other cases, the saturation was all under 0.9, therefore, we considered them equal except Case 4.
- For traffic-flow simulation, we made the ranking through the comprehensive evaluation of all indices.

Table 7 Evaluation Results by Traffic-Flow Simulation

Evaluation Items		Case1	Case2	Case3	Case4
Average delay time (Irifune)	Delay time (improvement level indices)	117.2 96.5sec/veh (17.7%)	117.2 101.6sec/veh (13.3%)	117.2 91.4sec/veh (22.0%)	117.2 90.5sec/veh (22.8%)
	Money loss by time-loss	359 thousand yen	338 thousand yen	358thousand yen	381 thousand yen
Relief of traffic congestion (Irifune)	The longest vehicle queue (m)	North direction 520 160(-360m) Irifune off-ramp 448 80(-368m)	North direction 520 160(-360m) Irifune off-ramp 448 24(-424m)	North direction 520 224(-296m)	North direction 520 184(-336m) Irifune off-ramp 448 88(-360m)
Shortening of travel time (Irifune)	Mean speed (km/h)	North direction 6.8 13.6(+6.8km/h) Irifune off-ramp 5.6 14.6(+9.0km/h)	North direction 6.8 14.8(+8.0km/h) Irifune off-ramp 5.6 41.4(+36km/h)	North direction 6.8 12.7(+5.9km/h) South direction 7.2 24.8(+18km/h)	North direction 6.8 13.5(+6.7km/h) Irifune off-ramp 5.6 5.8(+0.2km/h)
	Travel time (sec)	North direction 275 42(-233sec) Irifune off-ramp 288 20(-268sec)	North direction 275 39(-236sec) Irifune off-ramp 288 2(-286sec)	North direction 275 63(-212sec)	North direction 275 49(-226sec) Irifune off-ramp 288 55(-233sec)
In the total	Tendency in general	<ul style="list-style-type: none"> Improvement level index for north-south direction is high (32.0 ~ 68.4%) Vehicle queue in all intersections has a downward tendency Travel speed was up in north-south direction although that from east decreased 	<ul style="list-style-type: none"> Same as the Case 1 only the Improvement level index changed from 38.5% to 72.6% 	<ul style="list-style-type: none"> Vehicle queue and travel speed have a upward tendency at Toei-cho and Toko-cho in south direction 	<ul style="list-style-type: none"> Improvement level index for north-south direction is high (20.4 ~ 67.1%) Vehicle queue and travel speed have a upward tendency at Toei-cho and Toko-cho in south direction
	Money loss by time-loss	1,482 thousand yen	1,445 thousand yen	1,613 thousand yen	1,482 thousand yen
Conclusions		<ul style="list-style-type: none"> Effect for traffic congestion relief at Irifune by improvement of Ishinago-cho ramp is very remarkable It is the case having the least negative effect to Toko-cho and Hosobatakanan intersections 	<ul style="list-style-type: none"> It is the case being the most effective in all aspects With a sufficient improvement of elevated bridges, traffic of ground road decreased 	<ul style="list-style-type: none"> Being as without the improvement at south direction of elevated area, flows into plane crossings increased, and money loss by time-loss was largest There was little effect with Toei-cho and Toko-cho intersections 	<ul style="list-style-type: none"> Traffic congestion at Irifune off-ramp was improved by the lane addition to north side There was much negative effect for Toei-cho and Toko-cho intersections because 4 lanes improvement
		2	1	4	3

very effective , effective , poor effective

* A B: A=the result with the present condition, B=the result of the respective case

** Money loss by time-loss: Delay time × Traffic flow × Time value (used here as 56.00yen/min/passeanger-car, refer to Japan Research Institute)

Table 8 Comprehensive Evaluation

Methods	Case 1	Case 2	Case 3	Case 4
Ranking point by traffic assignment	1	1	1	1
Ranking point by saturation computation	1	1	1	4
Ranking point by traffic-flow simulation	2	1	4	3
Total ranking points	4	3	6	8
Rank by total ranking points	2	1	3	4

6. CONCLUSION

In this paper, we proposed an evaluation model system combining traffic assignment, saturation computation and traffic-flow simulation.

We applied this model system for the evaluation on the improvement plan of R156 in Gifu Prefecture of Japan, and showed its effectiveness.

Using this model system, we carried out the analysis of the local traffic condition in each intersection, and made the comparing evaluation on the improvement plans having been considered about the planning of the elevated bridges. As a result, we approached the best road improvement plan.

As the future topics, the follows can be summarized.

- The feedback of the simulation result to the traffic assignment: although we propose the model system with the feedback, we could not implement for the evaluation as the time limitation.
- Japanese Standard of Evaluation by LOS for the crossings: in this paper, we had considered LOS defined in HCM as one of the evaluation indices. However we could not apply it because the cycle length of traffic signal in Japan was so long that the thinking way is different from the basic idea of HCM.

REFERENCES

Chubu Regional Bureau of Japanese Ministry of Construction (Present: Ministry of Land, Infrastructure and Transport) (1998) An Outsourcing Report of Traffic Volume Estimation.

National Research Council (2000) Highway Capacity Manual 2000. TRANSPORTATION RESEARCH BOARD.

Japan Research Institute (2000) Guidelines for the Evaluation of Road Investment Projects.

Japan Road Association (1983) Notes on Road Structure Ordinance.

Japan Society of Traffic Engineers (1990) The Planning and Design of Grade Crossings.

Japan Society of Traffic Engineers (2001) Report on Traffic Census in 1999.