

Evaluation of City Planning Road Development Measures by Microscopic Traffic Simulation

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Abstract: This study was made on the development plan of Kawahara Avenue, a road project authorized in city planning of Miyazaki City in Japan. The purpose of this research is to study under the given constraints what would be the most appropriate plan for the development of Kawahara Avenue. First, a traffic monitoring survey was conducted in the subject districts to compile Origin-Destination (O-D) data of traffic flow in the districts. Then, the road network of the subject districts and traffic signal timing data were digitized to carry out microscopic traffic simulation (MITSIMLab) and checked for reproduction accuracy of the current situation. The results confirmed that simulation reproduces the traffic conditions of the districts with sufficient precision. Furthermore, we assumed two cases for the road development and evaluated with the same simulation system as to how the traffic situations would be had those cases been implemented. As a result it was demonstrated that the original goals could be achieved by developing the road within the given constraints.

1. Introduction

Miyazaki is a city with a population of roughly 300,000 and located in the southwestern region (Kyushu) of Japan. The major industries are tourism and agriculture. The city enjoys a temperate climate due to the warming effect of the Japan Current flowing along the Pacific coast. The city's coastline extends 30 km from north to south. The scenery along the line from Hitotsuba Beach with the beautiful pine groves and the Isle of Ao-shima thick with subtropical plants leading to Nichinan-kaigan Seminal Park features vivid tropical colors and draws more than 6 million tourists yearly. Recently large-scale resort facilities have been constructed based on the Miyazaki-Nichinan Coast Resort Plan designated under the Resort Law of Japan aiming at further increase of tourists.

As to the road conditions in Miyazaki, while arterial roads in the central commercial/business area and sightseeing area are well developed, access roads in residential and other such areas are mostly narrow and undeveloped, having many unsolved issues particularly in terms of safety.

The present research examines the improvement plan of Kawahara Avenue, a city planning road along the Oyodo River. Kawahara Avenue is a narrow road left without any improvement since the end of World War II and requiring immediate improvement. The road improvement project, however, involves several constraints. In the present research, we carry out traffic simulations by using MITSIMLab (a microscopic traffic simulator) to evaluate the effect to be expected from the road improvement under the given constraints. For evaluation, traffic flow volume of each link and other such factors before and after improvement are compared to conduct impact study.

2. Project Overview

An improvement plan of Kawahara Avenue was originally decided under city planning in 1946 as a part of the Reconstruction Plans After World War II. In the original plan the road was to have a width of 15 meters over the 1280 meters from Tachibana Bridge to Dekishima Town.

This plan was not implemented immediately, and underwent its first modification under city planning in 1955. It is because, in accordance with the Nine-Part Interim Directive on Stabilization given by the GHQ in 1948, the Reconstruction Plans were thoroughly reviewed as a national policy. As a result, the planned width of the avenue was changed from 15 meters to 8 meters.

Again, the modified plan was not implemented and underwent a second modification under city planning in 1975. In this modification, another 1,850-meter section from Dekishima Town to Takasu Town was added to the above-stated original section, extending the total improvement length to 3,130 meters. At this time, a major problem was left unsolved. Although the planned width for the added section was set to be 12 meters in accordance with the revised Road Structure Ordinance 1970, that for the original section was left unchanged from 8 meters. We were not able to find any documents of these days showing the reasons for the inconsistent widths. Presumably the then city government would have put off solutions due to objections to width expansion raised from the residents around the 8-meter section. The plan was never carried out even after the second modification to the present day.

The road development plan of Kawahara Avenue that had been left unimplemented for more than 50 postwar years finally began steps in 2003 toward implementation.

The project area is shown in Fig. 1, where the designated range of the road improvement is from point A to G. For section A ~ B, the city's leading tourist hotels stand along the road and road improvement has already been completed. The subject road range for the upcoming improvement project is from B to G, of which section B ~ F is for improvement of the existing road and section F ~ G is a new stretch of the road to be constructed. Presently section C ~ E includes a less-than-5-meter-wide eastbound one-way section. According to the plan, this section will allow two-way



Fig. 1 Project Area

traffic after improvement. Of the entire subject length of the project, planned width is 8 meters for section B ~ D and 12 meters for D ~ G.

3. Constrains and Financial Source for the Kawahara Avenue Improvement Project

The roads in the project area consist mostly of heavily housed narrow streets. With no sidewalks provided, they are not safe for pedestrian traffic, especially for children and the elderly, and therefore immediate improvement is called for. In addition, some vehicles use these narrow streets in the area as divert or alternate routes, which is a big problem bearing potential risk for traffic safety. In order to secure safe traffic environment in the area, motor traffic needs to be eliminated from these narrow streets as much as possible. To improve Kawahara Avenue so that the improved road would absorb the traffic demand in the subject area is considered to be an effective measure to realize it. As stated above, present Kawahara Avenue has a one-way section. Since the detour traffic blocked out from this part of Kawahara Avenue enters the residential area, elimination of the one-way section should also be an effective means to solve the

problem.

When considering road improvement for Kawahara Avenue, we must take it into account that the avenue is required to serve as sightseeing road, access road as well as other functions. As stated earlier, there stand the city's leading tourist hotels along the section between Tachibana Bridge and Oyodo Bridge. In addition to enabling smooth traffic of large-scale sightseeing buses, it is essential in this road improvement project to give thorough attention to prevention of heavy congestion of through traffic, as image the tourists may have is an important consideration. Furthermore, since there is much housing along Kawahara Avenue and the road is a space closely related to everyday life of those residents, not only the perspective of traffic demand management but also consideration to safety of pedestrians and late night noise are required.

In view of this background, an improvement plan for Kawahara Avenue formulated only from the perspective of upgrading its vehicular traffic handling function is inadequate. Along with adequate control of traffic volume, creation of safe and comfortable space for pedestrians must be ensured.

In Japan's present urban planning road standards, a road width of 16 meters is a requisite for double-lane roads (one lane each way) with sidewalks on both sides. A planned width less than that disqualifies a project from the national government's subsidies for Urban Road Development Projects. For the subject road project, ideally it is desirable to modify the city planning again to have a width of 16 meters over the entire length. A broader width than presently planned, however, entails removing housing over a wider area. This presents quite a challenge in obtaining consent of the residents concerned. Moreover, Kawahara Avenue runs under the railroad track of JR Nippo Line to intersect, where the maximum road width is 8.3 meters. If the width for this crossing portion were to be broadened, construction of a temporary track would be needed on a side of the existing track. Changing the planned width would be difficult due to the obvious difficulties of securing fund for additional construction costs and land acquisition for the temporary track.

Therefore, as a more practically feasible measure to secure the minimum requirement for safe pedestrian space, we study providing a sidewalk of a minimum width on both sides for 12-meter wide sections, and only on one side for 8-meter wide sections. In this case, safety for pedestrians must be enhanced by setting a lower speed limit for the sections with the sidewalk only on one side considering that serving as a space closely related to everyday life of the residents in the area is a function of Kawahara Avenue. Specifically, the speed limit for the 8-meter-wide sections should be 30 km/h although 40 km/h is the desirable speed limit for 12-meter wide sections.

As stated above, the present plan cannot provide adequate road improvement due to the difficulty of obtaining consent from the residents along the road and financial constraints. Notwithstanding that, we decided to examine the effect of road improvement with the presently planned width because leaving this road as it is any longer is definitely undesirable. Yet, the irregular road width setting in the present plan is not necessarily a mere disadvantage, as it would potentially work to suppress traffic inflow to Kawahara Avenue.

For the source of funding, instead of some subsidy for Urban Road Development

Projects that is not available for this project, a subsidy for Comprehensive Support Projects for City Planning will be used.

4. Overview of MITSIMLab

MITSIMLab is a microscopic traffic simulator developed at MIT (Massachusetts Institute of Technology) in the U.S. Its major features are the following: (1) the program runs on Linux, theoretically with no restrictions on network scale (which depends only on computer specifications); (2) routing logic based on discrete choice models is provided; (3) many control devices for traffic signals, etc. and surveillance systems including loop detectors are available.

The entire construction of MITSIMLab is illustrated in Fig. 2. The model consists of four modules: namely, (1) Surveillance System; (2) Traffic Management Simulator; (3) Control and Routing Device; and (4) Microscopic Traffic Simulator). These modules are executed in a sequential order repeatedly.

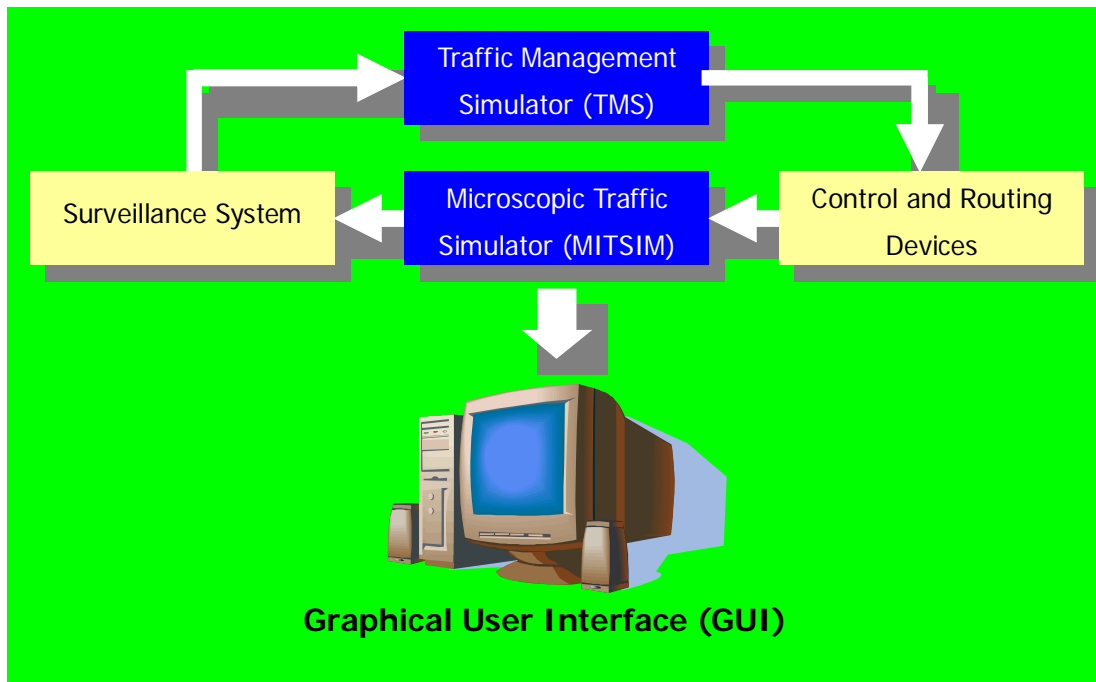


Fig. 2 Entire Construction of MITSIMLab

4.1 Network Representation

Network consists of links and nodes. Each link consists of segments, each of which consists of lanes. Each segment has data on the starting-/ending-point coordinates, speed limit, free flow speed, gradient, and bulge. Each lane has information as to acceptable types of vehicles (HOV, ETC), whether lane changes allowed or not, etc. In addition, downstream lane(s) to which a vehicle running on a lane can enter can be defined as the lane connector. Furthermore, control devices for traffic signals, etc. and

various sensors can be placed, and traffic restrictions due to of accident can be represented for each lane.

4.2 Vehicle Movement Logic

Individual vehicles on network make discrete movement by step size. Usually the step size is set at 0.1 second.

Major models of vehicle movement are (1) Car Following Model, (2) Lane Changing Model, and (3) Merging Model. The Car Following Model is represented as a function based on speed of subject vehicle, distance between subject vehicle and its leader, density of traffic ahead of subject vehicle, and speed difference between the leader and subject vehicle. There are two types of lane changes, mandatory lane change before turning right or left and discretionary lane change for passing or overtaking. Discretionary lane changes are stochastically simulated taking account of gaps in the target lane, speed of vehicle, distance from vehicle to downstream node (or lane drop), and other relevant factors. For merging, as well, stochastic simulation is made by evaluating the number of vehicles allowed in the merge area, probability of aggressive merge and other such relevant factors.

4.3 Demand and Routing

For demand, the number of vehicles per hour for each O-D pair is set. Demand setting can be varied by any period of time to simulate the changes in traffic volume according to time period. For vehicle types, (1) New Cars, (2) Old Cars, (3) Taxis, (4) Buses, (5) Trucks, and (6) Trailer Trucks are provided, and percentage in the entire traffic, typical length, and acceleration/deceleration scales can be set for each type as the parameters.

For routing of individual vehicles, a stochastic decision is made on the C-Lodit Model with travel time for each route as the variable. Here the vehicles are categorized into either the predefined route group or the non-predefined route group. The group with a predefined route will change the route only when more than a given level of time reduction can be expected. In contrast, for the group without a predefined route, a stochastic decision will be made for the route after the next node whenever reaching a node. Each vehicle will be further classified into the guided group with traffic information or the unguided group without. The guided group selects route by real-time travel time while the unguided group does by historical travel time. In this research, all vehicles select route by historical travel time since traffic information is not provided in the subject area of the present analysis.

4.4 Output

By executing MITSIMLab, the status of traffic is shown on the display in the form of graphical animation (Fig. 3), and at the same time the following data are output:

- Link-specific / Segment-specific Traffic Flow Volume
- Link-specific / Segment-specific Travel Time
- Trajectory (Positions of all vehicles on the network)

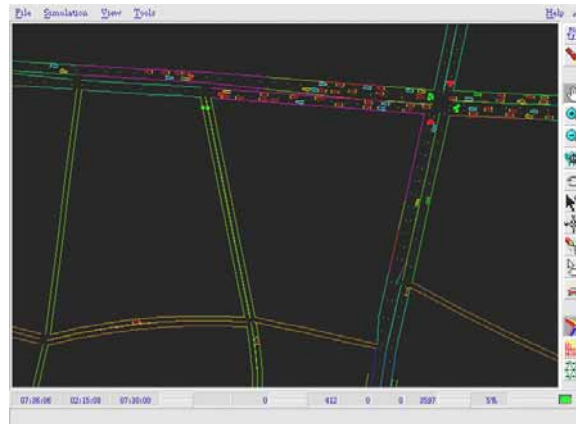


Fig. 3 Graphical Animation

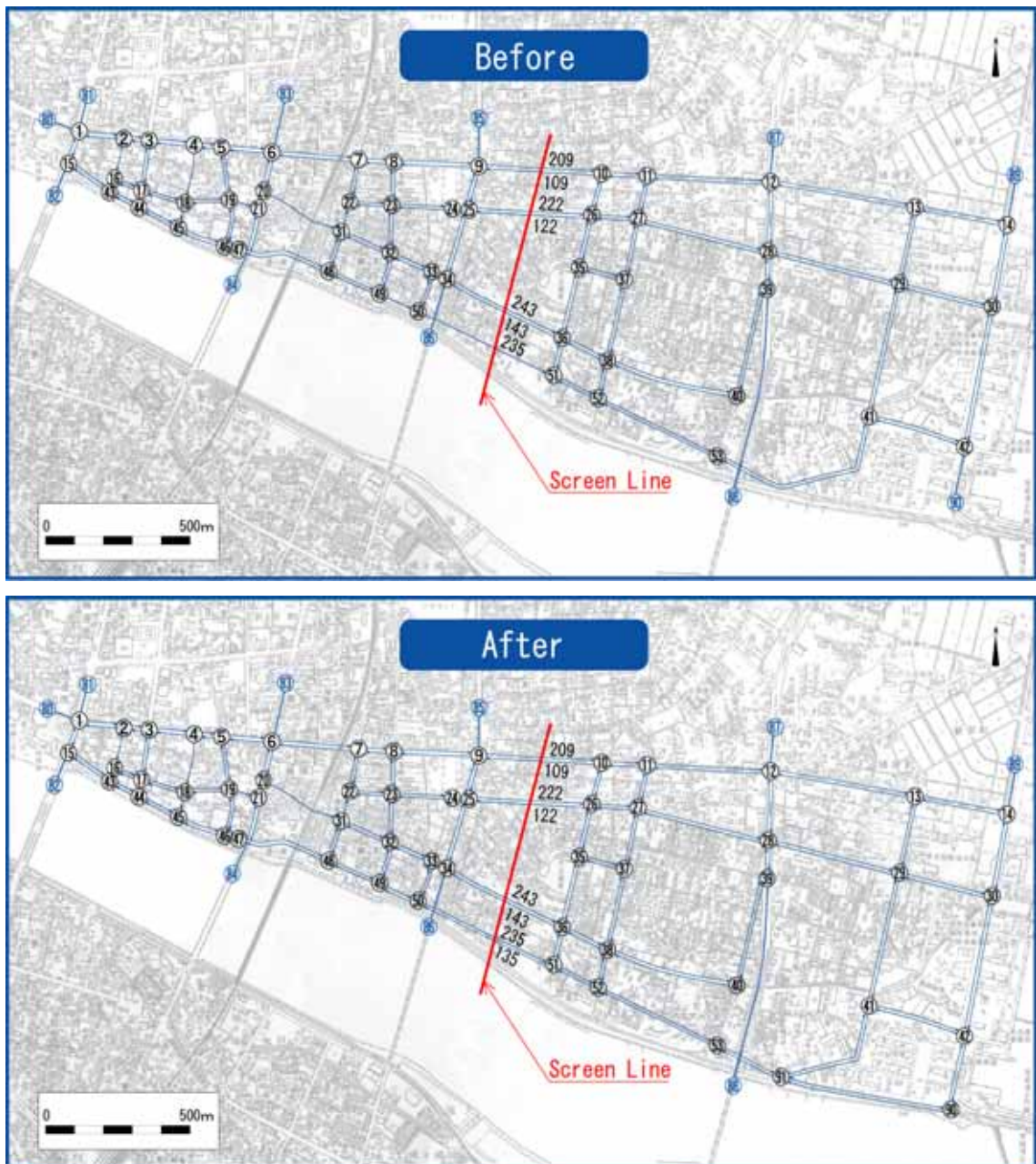


Fig. 4 Road Network

5. Subject Network and Input Data

The road network to be analyzed in this research is as shown in Fig. 4. We dealt with only those roads with relatively heavy traffic. The numbers in the figure denote the nodes and the solid lines connecting the nodes denote the links. The links are set individually for a direction: that is, the section at which traffic in both directions is allowed will have two links between two nodes, but there is only one link for a one-way road.

The road between nodes 81 and 14 is an arterial line called Asahi Avenue. Once Kawahara Avenue improvement work is completed, some degree of demand is anticipated to shift from Asahi Avenue to Kawahara Avenue. Besides 81 ~ 14, links between nodes 81 ~ 82, 83 ~ 84, 85 ~ 86, 87 ~ 88, and 89 ~ 90 are arterial roads.

For the demand data, traffic volume survey and number plate survey were conducted at major intersections to compile O-D data based on the survey results. The subject time range for analysis is 12 hours from 7 in the morning to 7 in the evening, and data were prepared by hour, totally 12 sets.

Traffic signal data were prepared based on the signal timing data obtained from Miyazaki Prefecture Police Department.

6. Reproduction Accuracy of Simulation

In the present analysis a screen line was set at the location shown on Fig. 4 in order to ascertain reproduction accuracy of simulation. In Fig. 5 the actual traffic volumes

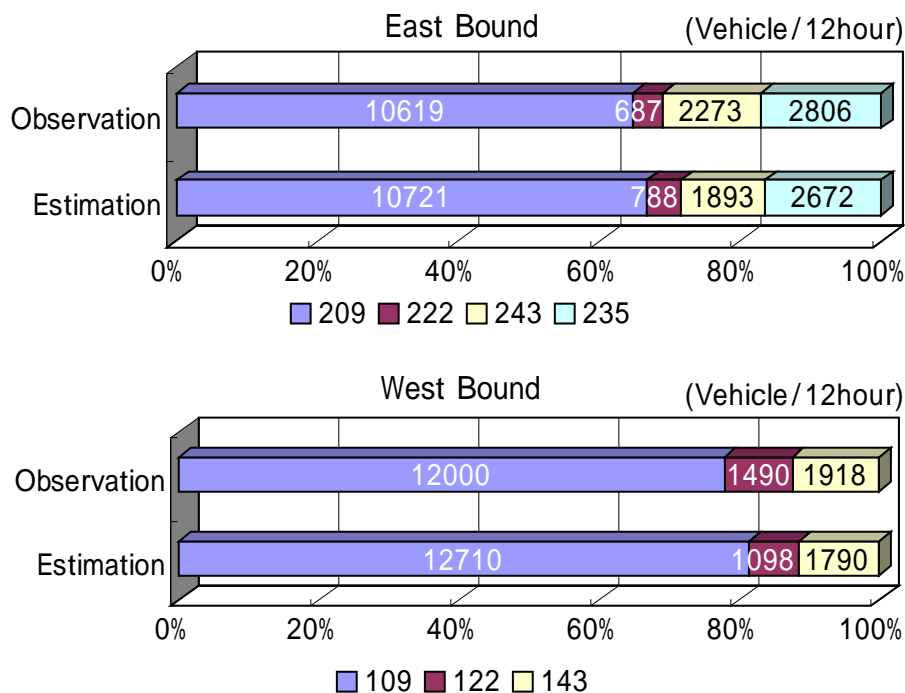


Fig. 5 Comparison between Observation Volume and Estimation Volume

during the 12 survey hours at each link are compared with traffic volumes obtained by simulation. The actual and simulated traffic volumes appear to have generally identical tendency on the figure. The correlation coefficient between the two categories of data was $r = 0.999$.

Taking into account the following factors, it is fair to judge that the simulation has sufficiently effective capability of reproducing the actual circumstances. These factors are: the demand data used in the present analysis are for one day only; data include some potential error entailed in OD traffic volume forecasts; and the actual traffic volume data are combined data from surveys conducted on two different days.

7. Impact Study for the Improvement of Kawahara Avenue

7.1 Assumed Cases

This section compares the conditions before and after implementation of the improvement project of Kawahara Avenue, and analyzes the effects of the improvement. Post-improvement conditions to be examined are for the following two cases.

Case 1 is when the planned improvement is to be carried out under the existing constraints, in which the speed limits are 30 km/h for 8-m wide road sections and 40 km/h for 12-m wide sections. For Case 2, assumption is based on when an ideal improvement is to be conducted, in which the speed limit for the entire sections is 40 km/h.

7.2 Changes in Traffic Volume on the Screen Line before and after Improvement

Fig. 6 shows comparison of the link traffic volume on the screen line before and after improvement. On this figure, as one-way section is eliminated after improvement, a new link 135 is added. After improvement, for both Cases 1 and 2, Kawahara Avenue (links 135 and 235) will have an increased demand and the other links will have a decreased demand. That is, after improvement of Kawahara Avenue, not only Asahi Avenue (links 109 and 209) but also the narrow streets within the area (links 122, 222, 143 and 243) are expected to have decreased traffic volume. We can see that the closer the link is to Kawahara Avenue, the greater the decrease rate in traffic volume.

A comparison between Case 1 and 2 after improvement shows that the traffic volume decrease rate for Case 2 is generally higher than that for Case 1, but the difference is not significant. This means that, compared to the pre-improvement condition, the effect of Case 1 improvement is significant, whereas the higher level of improvement in Case 2 does not generate a greater effect.

Regarding the difference between the eastbound and westbound traffics, the westbound link 143 shows a larger decrease rate in traffic volume. The reason can be the elimination of the one-way section from Kawahara Avenue. For other streets, the difference between the eastbound and westbound traffic volumes is not significant.

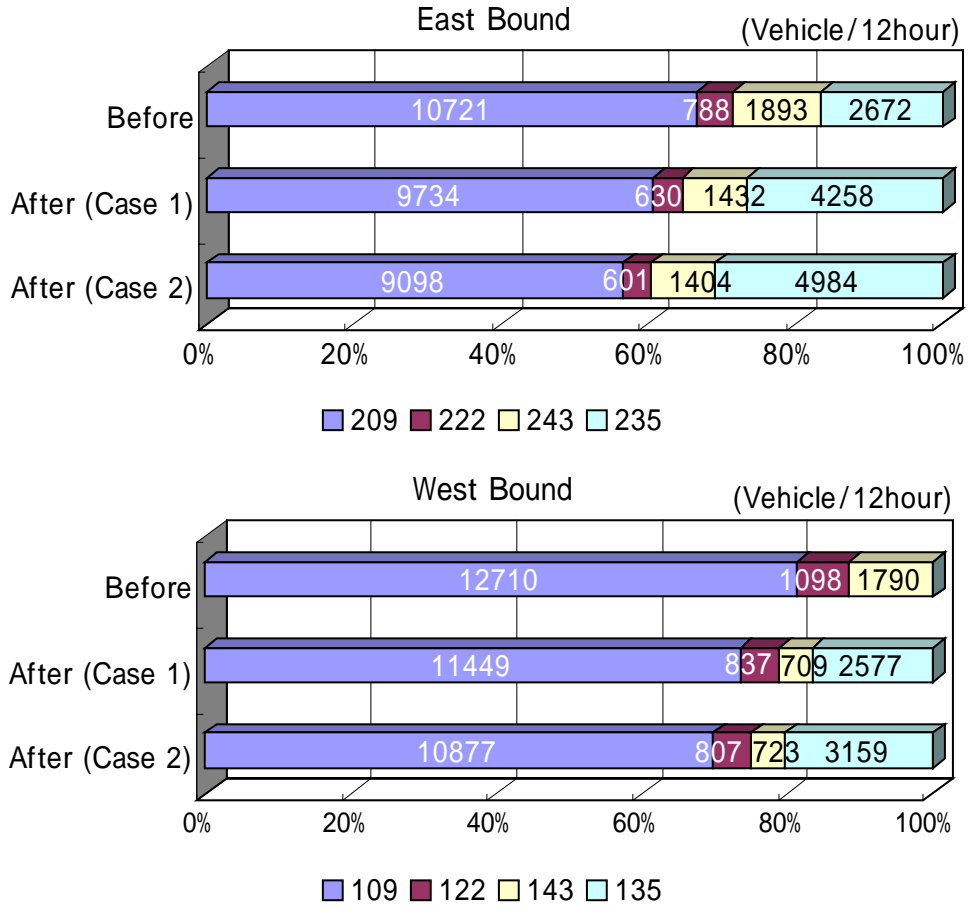


Fig. 6 Comparison of Traffic Volume on Screen Line before and after Improvement

7.3 Traffic Volume Shifted from Asahi Avenue after Improvement of Kawahara Avenue

The next examination is on the traffic volume shifted from Asahi Avenue after improvement of Kawahara Avenue. The average traffic volume for each avenue was found by the following calculation: 12-hour traffic volume of each link predicted by simulation was multiplied by the link length, then thus found values were added up for each avenue, and finally the sum of each avenue was divided by the entire avenue length. The calculation formula is shown below.

$$Q_i = \frac{\sum_j q_{ij} \times \ell_{ij}}{\sum_j \ell_{ij}} \quad (1)$$

Where,

Q_i : Average traffic volume for each street (i=1: Asahi Ave., i=2: Kawahara Ave.)

q_{ij} : Link traffic volume (j: link number)

ℓ_{ij} : Link length

Fig. 7 shows the average traffic volume by direction for Asahi Avenue and Kawahara

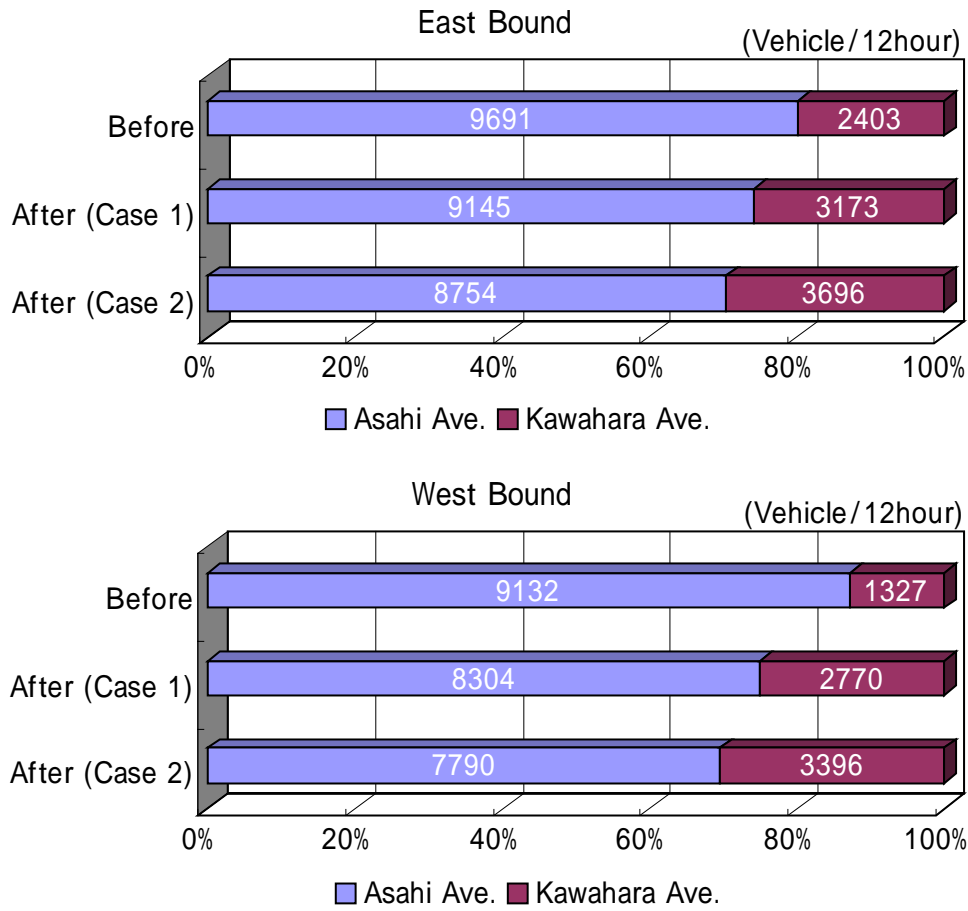


Fig. 7 Average Traffic Volume by Direction for Asahi Avenue and Kawahara Avenue

Avenue. The figure illustrates that a portion of the Asahi Avenue traffic volume was shifted to Kawahara Avenue after improvement as compared to before improvement. Between the cases, the shifted traffic volume is greater for Case 2 than for Case 1. Regarding the direction, the Kawahara Avenue average traffic volume for Case 1 increases roughly 1.3 times for eastbound and roughly 2.1 times for westbound, and for Case 2 the traffic volume increases roughly 1.5 times for eastbound and roughly 2.6 times for westbound. This shows that the shift rate of westbound is larger than that of eastbound. The reason is that the pre-improvement eastbound one-way section is converted to two-way traffic, realizing two-way traffic over the entire length after improvement.

Regarding the average traffic volume (per 12 hours daytime) for both directions, the total average quantity before improvement is 3,730 vehicles, which will increase to 5,943 in Case 1. We can see that this traffic volume will not incur serious traffic congestion. For Case 2, the number increases to reach 7,092, which is not of a level that will cause serious traffic congestion, either.

7.4 Total Travel Time

Fig. 8 shows the comparison between the total travel time on subject area before and after improvement. A roughly 5% reduction is achieved in Case 1 after improvement,

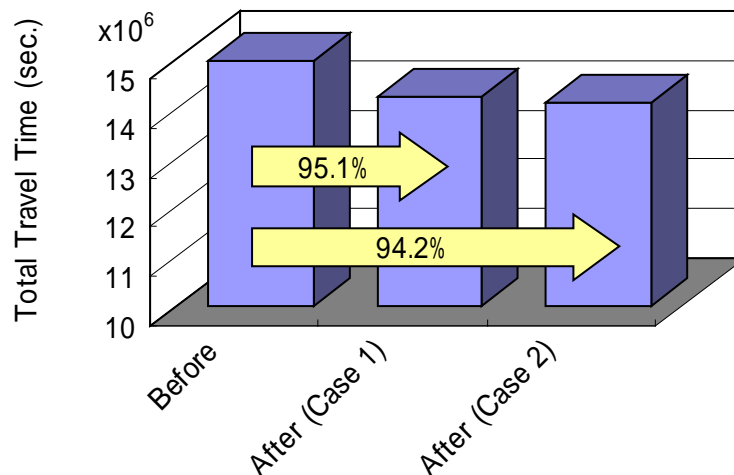


Fig. 8 Comparison between Total Travel Time before and after improvement

and a slightly larger reduction is achieved in Case 2, although the difference is not significant.

8. Conclusion

For Kawahara Avenue that cannot be given adequate improvement due to problems including consent of residents in the vicinity and financial resources, the present research evaluated, through the microscopic traffic simulation, the effects of improvement under existing constraints.

The results showed that the traffic volume on the narrow streets in the residential area could be reduced. Therefore, improved safety can be secured on narrow streets in the residential area. Due to the shifted traffic from Asahi Avenue, the traffic demand on Kawahara Avenue was assumed to increase. However, we confirmed that the increased traffic volume would not incur serious traffic congestion. In addition, it is forecasted that the planned improvement of Kawahara Avenue will reduce the total travel time within the subject area for analysis, increase convenience and lead to reduction of the load on the environment.

As explained above, it was confirmed that although the current improvement plan is not necessarily adequate, its implementation would fulfill the goals to a certain degree.

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